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AN EVALUATION OF THE REPLACEMENT
CRITERIA FOR SELECT AIR FORCE
COMMERCIAL GENERAL PURPOSE MOTOR
VEHICLES

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The Air Force Motor Vehicle Program employs three criteria with which to determine the eligibility of a vehicle for replacement: age, accumulated mileage, and repair costs. These criteria were developed in 1962 and have not been subjected to critical analysis since that date. This thesis evaluates the effectiveness of the Air Force replacement criteria using the sedan, station wagon and pickup truck as sample vehicles. The first portion of the thesis compares the Air Force vehicle replacement methods with programs used by various commercial activities. The results indicate that the Air Force program is superior to most of the commercial programs primarily because of detailed program documentation and extensive historical utilization data. The second portion of the thesis evaluates the effectiveness of the replacement criteria "age" and "accumulated mileage" through multiple regression analysis and statistical tests. The data used for this analysis consists of Vehicle Integrated Management System (VIMS) data from the Air Force Logistics Command (AFLC) and Air University (AU) for the period 1 October 1972 to 30 September 1973. The results indicate that accumulated mileage is a valid consideration for replacement, but that the age of a vehicle does not provide adequate justification for replacement of that vehicle.
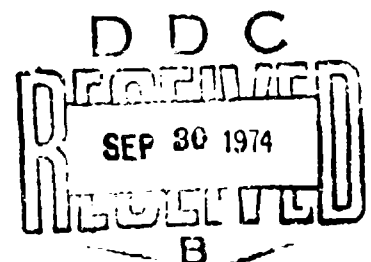
AN EVALUATION OF THE REPLACEMENT
CRITERIA FOR SELECT AIR FORCE
COMMERCIAL GENERAL PURPOSE
MOTOR VEHICLES

John A. Reidy, Jr., Major, USAF
Donald A. Schneider, Major, USAF

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AN EVALUATION OF THE REPLACEMENT CRITERIA

FOR SELECT AIR FORCE COMMERCIAL GENERAL PURPOSE

MOTOR VEHICLES

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

John A. Reidy, Jr., BS   Donald A. Schneider, BS
Major, USAF   Major, USAF

August 1974

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This thesis, written by

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and approved in an oral examination, has been accepted by
the undersigned on behalf of the faculty of the School of
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COMMITTEE CHAIRMAN

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CHAPTER I

PROBLEM

Statement of the Problem

The goal of the Air Force Motor Vehicle Program is to provide effective support to Air Force organizations at minimum overall cost. To accomplish this goal, it is necessary that vehicles be scheduled for replacement at such a time as to minimize total cost of ownership. To minimize costs of ownership and operation, it is desirable that the Air Force procure replacements for only those vehicles which are no longer economically retainable.

The vehicle replacement coding system for commercial general purpose vehicles was developed in 1962. The data and experience which were available at that time were limited; therefore, the factors which were developed were somewhat arbitrary (20). With the advent of new maintenance and utilization reports, data may exist to provide an evaluation of the quality of the commercial motor vehicle replacement coding system.

Definition of Terms

Throughout this thesis references are made to criteria, variables, and factors. For the purpose of this thesis a criterion will be considered as a standard, rule, or test

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used to form a decision to keep or replace a vehicle. The criterion is composed of two parts, a variable and a factor. In this thesis, the variable is defined as an attribute which may assume a succession of values which need not be constant. Examples of such variables that will be frequently mentioned are age, mileage, and one time repair limits. A factor will be the value or coefficient assigned to a variable. An example of a factor which would be used with the variable "miles" is 72,000. The factor and variable combined (i.e., 72,000 miles) form a criterion.

In addition, numerous references will be made to the economic life span of a vehicle. As used in this thesis, the economic life span of a vehicle refers to the period of time that a vehicle can be operated with a continual decline in the vehicle's average annual cost. In other words, the economic life span of a vehicle will start when it is new and end at such time that its average annual costs change from a decreasing trend to an increasing trend. Annual costs include all costs associated with the ownership of the vehicle such as depreciation, operation, maintenance, downtime, etc. Figure 1-1 illustrates the economic life span of a vehicle.

Background

The replacement program for motor vehicles within the military services has been subjected to close scrutiny, both from within the Department of Defense and by Congress. For
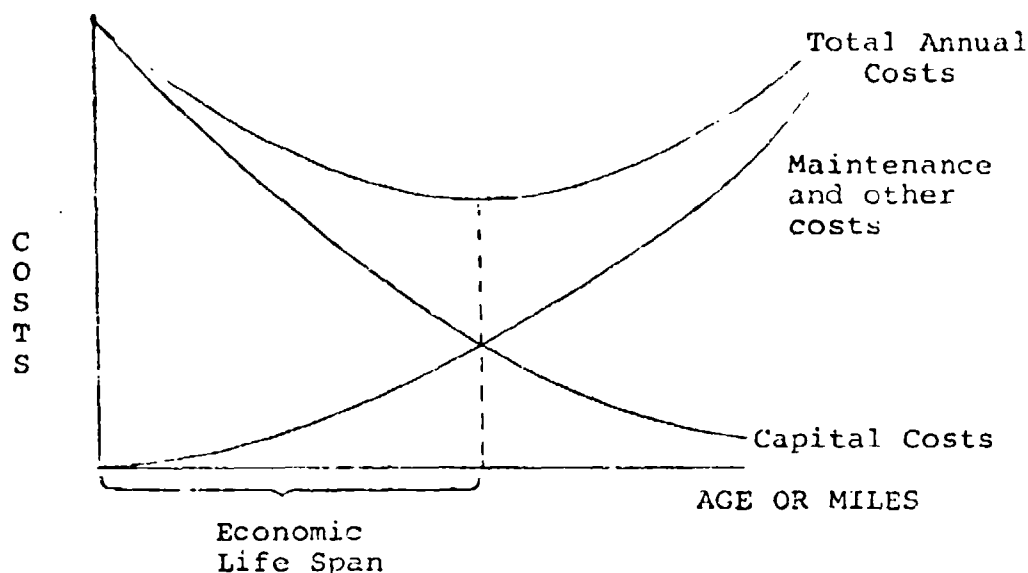
Figure 1-1

example, during the Department of Defense Appropriations

Hearings for 1968, Congressman Robert L. F. Sikes (Florida)

expressed Congressional concern by stating: "I question

whether the services are getting as much wear out of a

vehicle as they could [45:104]."

The USAF Auditor General has also expressed concern

regarding the replacement criteria for motor vehicles. In

a report of audit conducted in 1967, the Auditor General

criticized the use of age as a replacement variable. He

recommended that mileage and maintenance costs be considered

the primary variables for ascertaining vehicle replacement

requirements (35:Tab A2).

The USAF Inspector General summarized the problem in a

report of inspection conducted in 1970 (41:3) by stating:

> For several years, congressional committees have
> not been convinced that the Air Force vehicle
> requirements computation methods were reliable.
> As a result, buy programs have been subjected to
> reduction, partially because AFLC and the Air
> Staff had not defined any clear-cut criteria or
> logic for determining vehicle requirements.

The replacement criteria currently utilized evolved
from a Department of Defense (DOD) Ad Hoc Committee report
in 1962 which provided an age and mileage variable for each
major type of motor vehicle (e.g., sedan, pickup, ambulance,
etc.). Unfortunately, the source data available to estab-
lish the basic variables and factors were extremely limited
and, as a result, the criteria developed were arbitrary (20).

The results of the DOD Ad Hoc Committee of 1962 formed
the basis of Department of Defense Instruction (DODI)
4150.4, Replacement and Repair Guidance and Life Expectan-
cies for Commercial Design Vehicles, dated 5 April 1963,
which prescribed specific replacement criteria for various
types of commercial vehicles (see Table 1-1 for selected DOD
life expectancy years and miles for commercial design
vehicles) (44:Table I).

The Air Force implemented the DOD Instruction by pub-
lishing Air Force Technical Order (TO) 36A-1-70, Maximum
Repair Allowances, Condition and Management Codes for USAF
Vehicles, on 10 June 1964. In TO 36A-1-70, the Air Force
established four replacement codes ("A" through "D"). The
proper code was to be assigned to each vehicle to indicate
its condition as follows:

Table 1-1

SELECTED DOD LIFE EXPECTANCIES

Vehicle Type	Life Expectancy Years	Miles
Sedan	6	72,000
Bus, 37 passenger	8	84,000
Pickup Truck	6	72,000
Ambulance	8	60,000
Truck Tractor, 24,000-44,500 pounds	10	150,000

SOURCE: USAF TO 00-25-249, Maximum Repair Allowances, Replacement Codes and Priority Buy Program for USAF Vehicles, 22 January 1973.

Code A: Used to identify a vehicle eligible for immediate replacement because one or any combination of the three replacement criteria had been exceeded.

Code B: Used to identify a vehicle eligible for replacement within one year because of exceeding the age or miles criterion.

Code C: Used to identify a vehicle eligible for replacement within two years because of exceeding the age or miles criterion.

Code D: Used to identify a "new" or "like new" vehicle which had over two years of life remaining [37:6].

The technical order also provided a series of tables for each type of vehicle which prescribed the maximum amount of funds that could be expended at any one time for the repair of a vehicle. Each table provided an allowance factor

based on the age and miles accumulated by that vehicle. The appropriate allowance factor was selected by determining which variable (age or miles) provided the smaller factor. The allowance factor was multiplied by the acquisition cost for that vehicle to determine the one time repair limit. The following example describes the repair allowance table and provides calculations for a light sedan.

EXAMPLE: A light sedan has a life expectancy of six years and 72,000 miles. The maximum one time repair allowance factors for the light sedan are:

Accumulated Age (years):   1   2   3   4   5   6

Accumulated Mileage
            (thousands):   12   24   36   48   60   72

Maximum One Time Repair
        Allowance Factor: 83% 67% 50% 33% 17%   5%

In the fifth year, only $476.00 should be spent on a sedan based on a unit cost of $2,800, provided the mileage criterion had not been exceeded. For a four year old vehicle which has accumulated 72,000 miles, only $140.00 would be allowed for one time repair (i.e., .05 x $2,800). All costs, direct and indirect, are included in the expenditure consideration. Direct costs are those material and labor expenses which can be identified to the repair of a specific vehicle. Indirect costs for this vehicle include a proportionate share of expenses associated with the repair process, but cannot be directly attributed to any specific repair job [16].

Until 1967, exceeding any of the three replacement criteria of age, miles, and one time repair limit contained in TO 36A-1-70 was sufficient justification to assign code "A" to a vehicle (15). In 1967, Headquarters United States Air Force (HQ USAF) (36) directed that vehicle replacement

would be accomplished in the following order of priorities:

Priority I: This priority would identify those vehicles which had exceeded any combination of two elements or replacement criteria (i.e., age and miles, age and one time repair, or miles and one time repair).

Priority II: This priority would identify those vehicles which had exceeded the one time repair allowance.

Priority III: This priority would identify those vehicles which had exceeded either the age or the miles criterion.

The Air Force policy then included only those vehicles which had exceeded two of the three criteria as part of the budget request to Congress.

Brigadier General A. A. Riemondy, Director of Supply and Services, Deputy Chief of Staff for Systems and Logistics, HQ USAF, explained to the House Appropriations Committee that the Air Force had calculated vehicle replacement requirements for the past two years by applying two of the three criteria at the same time rather than just letting one of the criteria prevail. When questioned further the following year by the House Appropriations Committee, General Riemondy stated that the Air Force had realized savings in excess of $22.8 million since the procedure had begun three years earlier (46:471; 47:542).

In 1968 and 1969, Congress requested that additional detail be provided as part of the justification for funding the Air Force budget request for motor vehicles. In essence,

Congress asked for the specific reasons that the "A" coded vehicles had to be replaced. To secure the required data, it was necessary for HQ USAF to request that each command identify how many vehicles met each of the replace criterion established. To identify the specific criterion necessitated a more extensive and costly definition process than had been required under the three priorities for replacement established in 1967 (18).

In consideration of the requirement by Congress to identify specific reasons for replacement, the Air Force stratified the four replacement codes ("A" through "D") to a system of 16 codes. See Table 1-2 for a comparison of the old and the new replacement codes (37:6; 38:5-1). The stratified coding system not only permitted the Air Force to provide the necessary detail to Congress for budget justification, but it also provided a more detailed evaluation of the Air Force motor vehicle fleet for management purposes. The new coding system was formally implemented by the publishing of the revised TO 36A-1-70 on 15 July 1970.

In 1971, the Air Force began to experience the impacts of the previous Air Force policy of replacing only those vehicles which met a combination of two of the three replacement criteria. An analysis by the Air Force Logistics Command (AFLC) during 1972 revealed that support costs for the vehicle inventory had significantly increased between Fiscal Year (FY) 1971 and FY 1972. Support costs for the commercial general purpose portion of the USAF fleet, for

Table 1-2

COMPARISON OF OLD AND NEW (STRATIFIED) REPLACEMENT CODES

Old Codes	New (Stratified) Codes
A -- Replace immediately, has exceeded one or more of the three replacement criteria.	A -- Replace immediately, has exceeded all three replacement criteria.
	B -- Replace immediately, has exceeded both age and one time repair limit.
	C -- Replace immediately, has exceeded both miles and one time repair limit.
	D -- Replace immediately, exceeds the one time repair limit.
	E -- Reserved for special reporting.
	F -- Replace immediately, obsolete.
	G -- Replace immediately, has exceeded both age and miles criteria.
	H -- Replace immediately, has exceeded the age criterion.
	J -- Replace immediately, has exceeded the miles criterion.
B -- Replace within one year.	K -- Replace in one year, will exceed both age and miles criteria.
	L -- Replace in one year, will exceed the age criterion.
	M -- Replace in one year, will exceed the miles criterion.

Table 1-2 (Cont)

C -- Replace within two years.

N -- Replace in two years, will exceed both the age and miles criteria.

P -- Replace in two years, will exceed the age criterion.

Q -- Replace in two years, will exceed the miles criterion.

D -- Over two years life remaining.

R -- To be assigned when:

    (1)   Codes A through Q do not apply.

    (2)   A vehicle has been repaired by depot level maintenance.

    (3)   A vehicle has been remanufactured with a new registration number.

SOURCE: USAF TO 36A-1-70, Maximum Repair Allowances, Replacement Codes and Priority Buy Program for USAF Vehicles, 10 June 1964 and 22 January 1973.

example, had increased over $110.00 per vehicle in the time period analyzed. Expanding that average increase over the entire Air Force vehicle fleet, there was an increase of over $10.5 million in vehicle support costs in one fiscal year alone (39:5). Therefore, beginning with the FY 1972 Procurement Program, the Air Force returned to the previous policy of considering a vehicle eligible for replacement when only one of the three criterion was exceeded.

After over two years of experience with the stratified replacement codes, the Air Force determined that additional

codes would be necessary to provide identification o

specific periods in a vehicle's life. As a result, a tion

was initiated in 1973 to restructure and add the following

codes:

Code R: Assigned when a vehicle has reached one-half
(mid-life) of its normal life expectancy for
either the age or the miles criterion.

Code S: Assigned to a vehicle which has been repaired
by depot level maintenance. The vehicle will
remain in this code for 48 months, at which
time it will be assigned the applicable code
based on the accumulated age, miles, or repair
costs.

Code T: Assigned when codes A through S or code U do
not apply.

Code U: Assigned to a vehicle which is under war anty,
either from the original manufacturer or the
Air Force remanufacture program. Upon expira-
tion of the warranty, the vehicle will be
assigned the proper code commensurate with the
accumulated age and miles [34].

Scope

For the purpose of this thesis the term commercial

general purpose vehicle will be used to describe a vehicle

designed by the manufacturer as a production model for com-

petitive commercial sale and usage. A commercial vehicle is

built to the manufacturer's specifications and is purchased

by the Air Force without major changes to the manufacturer's

general specifications. For consideration in this thesis the

term general purpose vehicle will be limited to vehicles

weighing less than 12,000 pounds and will not include special

purpose vehicles. Special purpose vehicles are vehicles

designed specifically to meet a special military require-
ment, such as aircraft towing tractors and fuel servicing
vehicles. Also excluded from this study are fire fighting,
materials handling, and base maintenance vehicles.

The 15 May 1974 Air Force motor vehicle fleet consisted
of 96,900 vehicles with a value of over $1.046 billion (16).
Within the 96,900 vehicles were 61,252 commercial general
purpose vehicles. Because of size and multiplicity of types
in the commercial general purpose vehicle category, the
researchers selected for analysis the light sedan, station
wagon and the pickup truck. The light sedan, station wagon
and pickup truck constituted 33% of the commercial general
purpose vehicle category and were used by all commands in
all climates (16).

The scope of this thesis was originally limited to
determining an optimal replacement point or the vehicles'
economic life span based on average annual cost. The
researchers recognize that other areas must be considered
to determine an overall optimum (i.e., maintenance manning
and facilities, spares availability, reliability). These
other areas will be addressed in evaluating the research
hypothesis.

Objectives

The primary purpose of this thesis was to determine the
validity of the current replacement criteria for commercial
general purpose motor vehicles within the Air Force. The
specific obectives were:

1. To determine what variables, factors, and analytical equations government and non-government activities employ as indicators to determine motor vehicle replacement requirements.

2. To develop the optimum combination of variables and factors to determine motor vehicle replacement requirements.

3. To determine if the Air Force is employing the optimum combination of variables and factors to identify motor vehicle replacement requirements.

Research Question

What variables and factors do government and non-government activities employ as criteria to determine motor vehicle replacement requirements?

Research Hypothesis

The Air Force does employ the proper combinations of variables and factors to determine motor vehicle replacement requirements.

Methodology

Data for the research question was collected from several different types of motor vehicle fleet managers. The sources were not intended to be random samples, nor necessarily statistically representative but were, as judged by the researchers, typical of the various types of activities using fleets of commercial general purpose motor vehicles. These data consisted of variables, factors, analytical equations, and procedures used by the activities

that responded to the researchers' request for information.

The data for the research hypothesis were obtained from HQ AFLC. These data were accumulated as the result of the testing of the Vehicle Integrated Management Reporting System (VIMS) in the Air Force Logistics Command and the Air University Command. These data consisted of vehicle mileage, age, maintenance cost, down time, operating costs, vehicle down for parts (VDP) time, vehicle out of commission (VOC) time, and direct labor hours.

Chapter II describes the procedures planned in obtaining the data for the research question and its analysis.

Chapter III describes the data received in response to the request sent to the various activities to answer the research question.

Chapter IV describes the procedures used in evaluating the research hypothesis and the results thereof.

Chapter V summarizes the results of the research question and research hypothesis and presents the conclusions drawn from the results, as well as recommendations made by the researchers.

CHAPTER II

RESEARCH QUESTION PROCEDURES

General

This chapter will describe in detail the methodology and data sources used by the researchers in evaluating the research question.

Research Question

What variables and factors do government and non-government activities employ as criteria to determine motor vehicle replacement requirements?

Data Required

The research question was intended to be used to obtain data with which to evaluate the research hypothesis. It was the intent of the researchers that these data consist of the procedures, analytical equations, variables, and factors used by government and non-government activities to determine commercial motor vehicle replacement requirements.

In this thesis, the v riable is defined as an attribute which may assume a succession of values which need not be constant. Examples of such variables that will be frequently mentioned in this thesis are age, mileage, and one time repair limits. A factor will be the value or

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coefficient assigned to a variable by which the variable and factor combination form a criterion. For example, the factor of "72,000" is combined with the variable "miles" to form a criterion "72,000 miles." An analytical equation is an expression of the relationship of selected factors and variables which produces a mathematical result. A procedure is the method or manner in which the activity proceeds to apply and process the variables and factors to determine when a vehicle should be replaced.

Source of Data

It was not the intent of the researchers to obtain a random sample of the procedures utilized by all activities using commercial general purpose motor vehicles. The intent was to obtain some idea of the procedures and variables used by several different types of motor vehicle fleet managers. The sources selected were, in the judgment of the researchers, typical of government and non-government activities using fleets of commercial general purpose motor vehicles. In order to provide for different usage rates and climatic conditions, the researchers selected varied types of activities in all parts of the continental United States (see Appendix A for the states selected by region). Requests for data were dispatched to municipalities, taxicab companies, rent-a-car agencies, utility companies, professional fleet management agencies, airline companies, and research activities. Government agencies which were contacted for

information included the General Services Administration
(GSA), the United States Postal Service (USPO), and the Ohio
State Department of Transportation. The four automobile
manufacturers were also requested to provide literature which
they might make available to fleet managers to assist in the
determination of motor vehicle replacement requirements.
The list of the 40 activities from which vehicle replacement
information was requested is found in Appendix B.

Nature of Data

The data gathered to evaluate this research question
consisted of procedures, variables, and factors used by the
selected activities to determine motor vehicle replacement
requirements. In addition, supportive data in the nature of
studies and historical reports were also provided by some
respondees.

Planned Analysis of Data

The data received from the sources referenced in
Appendix B were thoroughly screened and categorized to deter-
mine if there were any common variables, analytical equa-
tions, and factors. Once the data was categorized, tables
comparing the variables and factors used by the Air Force and
the variables and factors used by other activities were pre-
pared. As previously mentioned, the researchers' intent was
to list and analyze the various analytical equations pro-
vided by the various activities, giving a complete
explanation of how the equation was used. As shown in

Chapter III, the researchers obtained only two such analytical equations, one of which could not be disclosed and discussed due to proprietary rights. The other, provided by Public Technology, Inc., will be addressed in Chapter III. The information contained in these tables was intended to be used to evaluate the research hypothesis.

CHAPTER III

MOTOR VEHICLE REPLACEMENT PROCEDURE ANALYSIS

Background

As defined in Chapter I, the economic life span of a
vehicle is that period of time that a vehicle can be oper-
ated with a continual decline in the vehicle's average
annual costs. In the environment of the Federal Government
the annual costs associated with the ownership of the
vehicle may include such considerations as depreciation,
operations costs, maintenance costs, and down time.

During the life of a vehicle these costs may vary
according to different patterns--some increasing, some
remaining relative stable, and others decreasing through
time. As a group, they comprise the annual costs of the
vehicle and it is this annual cost that is applicable to the
determination of the economic life span of the vehicle and
the determination of when the vehicle should be replaced.

One source used by the researchers quite appropriately
addressed the relationships between these costs:

> Concentration upon one or the other of these cost
> elements without considering the total will most
> likely lead to a situation in which the equipment
> manager is suboptimizing, i.e., choosing replace-
> ment lives which lead to lower costs in one or
> more of the elements but result in higher over l
> costs [29:2].

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It is not uncommon in government activities, whether they are Federal, State, or Local City Governments, to find it easier to obtain operation and maintenance funds than it is to obtain a large capital outlay of funds for vehicle replacement. Therefore, the manager is often forced into the situation of suboptimization as described above. This situation is extremely unfortunate when in actual practice, the reduction in capital expenditures may be overbalanced by the rapidly escalating costs of maintenance, downtime, and obsolescence which result from holding equipment beyond its economic replacement point.

General

With this brief background, the researchers' first task was to obtain information from other activities as to how they addressed these cost relationships. Therefore, the remainder of this chapter will address the research question portion of this thesis. "What variables and factors do government and non-government activities employ as criteria to determine motor vehicle replacement requirements?"

The researchers believed that it was first necessary to use this procedure to obtain necessary data with which to evaluate the research hypothesis. The intent was to obtain data consisting of procedures, analytical equations, variables, and factors used by government and non-government activities to determine commercial motor vehicle replacement requirements.

Data Description

The scope of the thesis was limited so that the term
commercial general purpose vehicle described a vehicle
available from competitive commercial sources and was
restricted to a weight of 12,000 pounds or less. The term
general purpose vehicle excluded special purpose, fire
fighting, materials handling, and base maintenance vehicles.
To further limit the scope of the thesis, the universe
selected was limited to the light sedan, station wagon, and
pickup truck types of vehicle which constituted 33% of the
commercial general purpose vehicle category (16).

Data Source

As previously discussed in Chapter II, it was not the
intent of the researchers to obtain a random sample of the
procedures utilized by all activities, but to obtain some
idea of the procedures and variables used by several
different types of motor vehicle fleet managers. The
activities selected were believed by the researchers to be
typical of government and non-government activities using
fleets of commercial general purpose motor vehicles. As
previously mentioned, the researchers selected varied types
of activities in all parts of the continental United States
(see Appendix A for the states selected by region), so as to
provide for different usage rates and climatic conditions.

Requests for information were sent to 46 government and
non-government activities of which 25 responded with varied

types of data and information. In addition to those activities contacted by letter, the researchers made telephone contacts with four additional activities which were able to provide supplementary data. See Table 3-1 for a detailed breakdown of the activities contacted and responses received. The list of the activities from which vehicle replacement information was requested is found in Appendix B.

As a result of the researchers' requests for data, some activities provided the names of additional organizations that might be able to provide some assistance. Therefore, additional letters were sent and telephone contacts were made with these activities.

Nature of Letter Sent

The letters forwarded to the activities explained the purpose of the thesis being undertaken, the purpose of the information, the type of data requested and how the data would be used by the researchers. A sample of the general type of letter used is found in Appendix C. This letter was slightly modified as necessary to be appropriate for the agency addressed.

Data Received

It was originally hoped that the data received from the selected activities would consist of procedures, analytical equations, variables, and factors used by the activities to determine vehicle replacement requirements. It was also anticipated that supportive data in the nature of studies

Table 3-1

ACTIVITIES CONTACTED
AND
RESPONSES RECEIVED

	GOV'T ACT.	AUTO MFG CORP.	CAR LEASE CO.	AIR LINES	MUNIC.	UTIL. CO.	TAXICAB CO.	RESEARCH ACT.	AUTOMATED/ FLEET MGT CO.
LETTERS SENT	7	6	3	4	6	8	5	2	5
RESPONSES RECEIVED	3	3	1	2	4	3	1	2	3
*NEGATIVE RESPONSES		3	1	1	1	2	1		
**POSITIVE RESPONSES	3			1	3	1		2	3
ADDITIONAL TELEPHONE CONTACTS								2	2
**POSITIVE RESPONSES FM TELE. CONTACTS								1	2

* Those responses which indicated that they had no procedures or that their procedures were so subjective that no attempts were made to document them to the researchers.

** Those responses which indicated that their procedures were either objective or subjective and could be documented to the extent that they were of assistance in the evaluation of the research question.

Letters Sent Out	46	
Responses Received	22	47%
Positive Responses	13	28%

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and historical reports would be provided by some of the respondees.

As illustrated in Table 3-1, 47% of the addressees responded to the researchers' request for information. Of those that did respond, 59% (28% of the activities addressed) provided positive responses, that is, indicated that their procedures were either objective or subjective and could be documented to the extent that they were of assistance in the evaluation of the research question. The other 41% of the respondees indicated that they had no procedures or that their procedures were so subjective that no attempts were made to explain them to the researchers.

Only two of the respondees that actually operated a fleet of vehicles indicated that they had a definite procedure that they followed in determining their vehicle replacement requirements. The other fleet operators either let the determination be made by the maintenance personnel or the departmental personnel to which the vehicles were assigned with only rough guidelines set for criteria and variables. The variables used by the respondees, either in set procedures or guidelines, are illustrated in Table 3-2.

As shown in Table 3-2, there appeared to be very little similarity in the variables and factors used by the various activities. For example, none of the government activities that responded used the same factors. While there was some similarity in the ages of the vehicles, the miles used and consideration of other variables varied considerably. There

Table 3-2

VARIABLES/FACTORS USED BY RESPONDEES

			VARIABLES			
ACTIVITY	AGE/YRS	MILES	MAINT/OPER COST	DOWN TIME	OBSOLES-CENCE	TYPE OF VEHICLE
GOV'T:						
AF	6	72K	*			Sedan, station wagon and pickup
GSA	6	60K	*			Sedan and pickup
US POSTAL DEPT.	6	42K	*			1/4T pickup
	4	96K				1/2T pickup
OH DEPT TRANS.	3	65K				Sedan
	4					Pickup
AUTO MFR'S	NO VARIABLES OR CRITERIA PROVIDED					
AUTO LEASING	1	25K	1.44¢/mi.			
	2	40K	1.44¢/mi.			
AIRLINES:						
A	NO VARIABLES OR FACTORS PROVIDED					
B	*		*			All
MUNICIPALITIES:						
A	5	50K				Sedan
	7	70K				Pickup
B	6	60K	*	*	*	Sedan
	5	60K	*	*	*	Pickup
C	5	60K	*			Sedan
	8	60K	*			Pickup
UTIL. CO.	1-8	85K	2-3¢/mi.	*		Sedan
	7	100K	*	*		Pickup
TAXICAB CO.	DRIVER OWNED AND MAINTAINED					
RESEARCH ACT.						
A	*	*	*			All
B	*	*	*	*	*	All
AUTO/FLT MGT ACT						
ALL	*	*	*			All

* Identified as used but no factors given.

appeared to be closer similarities among the three munici-
palities, A, B, and C; however, this can be partially
explained by the fact that two of the municipalities are
using information and guidance provided by two of the
research activities contacted, American Public Works
Association and Public Technology, Inc. The American Public
Works Association and Public Technology, Inc., procedures
and information are further discussed in a later section of
this chapter.

Review of Responses

The primary thought behind soliciting information from
fleet managers throughout the nation was that the
researchers believed that in all probability the major
commercial and major municipalities fleet operators would be
using some management science method of determining when to
replace their vehicles. It was also believed that some of
the activities would have sufficient experience such that
they would be able to provide some vehicle historical data,
policies, procedures and recommendations as to how their
programs could be improved. So that the contacted activities
wouldn't believe that this information exchange was strictly
a one way flow--from them to the researchers--copies of the
abstract of the thesis were offered those activities that
provided assistance.

Contrary to expectations, very few of the fleet opera-
tors, excluding research activities and professional fleet
management agencies, that responded had any scientific

method of determining their vehicle replacement require-
ments. Most activities had only rough guidelines such as
approximately six years age, approximately 60,000 miles, and
some consideration given to maintenance costs, downtime, and
obsolescence. These guidelines were strictly informal and
applied only when and how the particular individual making
the determination believed applicable. No formal pro-
cedures were documented, so there was never any assurance
that the same variables, criteria, or factors were used
from time to time. The research activities and professional
fleet management agencies contacted seemed to have a good
grasp on the management science methods of vehicle replace-
ment determination.

A more detailed review of the responses by type of
activity will be provided in the following sections.

Government Activities

The U. S. Postal Department has established some pro-
cedures in their Postal Service Handbook M-2 for the
replacement of postal vehicles which are very similar to
those currently used by the Air Force, i.e., life expectancy
of six years, mileage expectancy of ,2,000 miles with repair
costs limited by a percentage of the vehicle contract price
according to age in years (48). Motor vehicle replacement
standards published by the General Services Administration
(GSA) indicate that, "Passenger cars and station wagons may
be replaced when they have been operated for six years or

60,000 miles whichever occurs first [14:3819]." GSA did
not indicate that any other variables were used nor that
any cost relationships were used in conjunction with these
criteria. Likewise, the Ohio Department of Transportation
indicates that they use years of use and mileage as guide-
lines but do not indicate any other variables or cost
relationships (24).

Automobile Manufacturers

The automobile manufacturing companies were addressed
with the idea that they may accomplish a certain amount of
operations research in an effort to assist fleet managers
in the determination of the optimum time to replace a
vehicle. It was found that of the companies that responded,
none provided the service mentioned nor did they have any
information in this regard (1;11;13).

Automobile Leasing Agencies

The automobile leasing agency that responded indicated
that they used mileage as the prime consideration for
passenger car replacement with secondary considerations
given to age and maintenance costs. If was noted, however,
that consideration was not given to retaining a vehicle over
two years of age (22). Even though the researchers previ-
ously believed that the response from the leasing agencies
would be similar to this, due to the leasee's interest in
cosmotology and body style currency, the researchers
believed that research of this nature would not be complete

without having made such contacts.

Airlines

Of the two airlines that replied, one indicated that they had no set criteria and replaced each vehicle based on a general subjective observation of its condition, age, etc. (8). Eastern Airlines indicated that they were working toward a computerized data collection system which would include a vehicle replacement program. At the time of their letter, however, they were required to operate with what they considered as an unsatisfactory replacement method that was based primarily upon subjective inputs from local management with little or no objective criteria for replacement (10).

The program that Eastern Airlines was in the process of establishing was designed to provide:

1. Accurate replacement forecasts for each motorized vehicle.

2. A basis for accurate budgeting of capital funds for ground equipment replacement programs.

3. A sound basis for replacing vehicles at the most economical period, thus reducing overall vehicle maintenance costs. (See Appendix D)

Taxicab Companies

The taxicab company that responded indicated that the vehicles were owned and maintained by the operators. Therefore, they did not have any information that would be

of assistance (4).

Utility Companies

None of the utility companies indicated that they had any procedures in writing so that the replacement determinations could be made objectively. Some of the respondees did indicate that they used maintenance costs, dependability (which is particularly important when responding to storm damage), and further subjective evaluation by their maintenance personnel (17;19;23).

Municipalities

One of the municipalities that responded indicated that they did not use any procedures other than the subjective opinion of the maintenance personnel or departmental personnel (7). One activity stated that they used mileage, age, dependability, and the advice of the city department to which the vehicle was assigned to determine their replacement requirements (21). Again, however, the replacement decisions were made subjectively and no procedures were documented for any objective considerations.

The City of Seattle (31) advised that historically they have used age and mileage as a "rule of thumb" method and had found that maintenance costs accounted for approximately 25% of the total ownership cost. They considered this 25% as a small rise in costs which did not justify a complicated method of determining optimum replacement time. At the time of their letter, the City of Seattle was participating with

the American Public Works Association (APWA) in developing
standards for defining and recording automotive costs with
the objective of creating a nationwide data bank that could
be used for comparisons. The APWA efforts will be addressed
in a later part of this chapter under Research Activities.

The City of San Francisco has developed a Recommended
Replacement Schedule for the various types of vehicles owned
by the city, which is generally accepted by their budget
authorities as being reasonable (32). Through their own
research, and the State of California Department of Public
Works, they have been able to verify that a general service
vehicle reaches its critical point at five years or 60,000
miles. They state that "At this point of service all
warranties have expired, the vehicle's dependability is
reduced, downtime increases, and major repairs are required
[Appendix E]."

Research Activities

In Research Project 70-1, the American Public Works
Association is developing a manual on equipment replacement
analysis. This project has concentrated upon the develop-
ment of local equipment management information systems as a
preliminary step to the establishment of a nationwide equip-
ment data bank (2). To insure that the data bank contains
accurate and valid data, APWA is establishing standards that
agencies must meet in order to input information to the data
bank. APWA states that "These standards will relate

primarily to the definition of terms, establishment of repair type (of vehicles) on which maintenance data are gathered, classification of vehicle types, and data bank input formats [2]." When the data bank is established, APWA will be able to provide requesting activities with vehicle operating data and life cycle cost data (2).

Since this project had not been completed at the time of their letter, the researchers were not able to further pursue this endeavor. The researchers recommend that further study and review of APWA Research Project 70-1 be conducted to determine if the Air Force could benefit from their findings.

In addition to the above works, APWA has published a Special Report No. 37, Motor Vehicle Fleet Management, which provides an:

> --equipment management system based on standards
> and exception reporting, standard interval main-
> tenance, parts inventory and warehouse control,
> physical and performance specifications, optimum
> utilization and replacement, and instrumentation
> to monitor performance and standards. It shows
> how to plot capital shrinkage and operating,
> maintenance, and downtime costs into a combined
> cost that reveals break-even point, earnings
> (savings), and replacement point [3:5].

Included in Appendix F is a reproduction of Chapter IX of Special Report No. 37 which addresses motor equipment replacement. The analytical model illustrated in the referenced chapter gives weight to many factors that affect the replacement decision.

The Public Technology Institute (PTI) has developed a

vehicle replacement model. This model systematically records the relevant costs which accumulate due to operation, maintenance, and vehicle depreciation; estimates the typical costs of keeping and replacing a vehicle; and compares a vehicle's performance against norms or set standards to detect exception (28:2). For this model the vehicles are grouped into functional vehicle classes. The grouped vehicle information is summarized to reflect past cost patterns which show economic lifetimes for each vehicle class. The model also calculates the anticipated economic lifetime for each specific vehicle compared to that of the average vehicle in its class and calculates the maximum amount of funds that are economically feasible to be spent on a one time repair action. The model provides the manager with the necessary information so that he can set and administer policies but will not make the final decision of whether to retain the vehicle or replace it. This decision is left to the manager after he has interpreted and applied his managerial judgment to the model's recommendations.

The Vehicle Replacement Package created by PTI consists of five computer programs with associated documentation (28:3):

1. A curve-fitting program.

2. An economic-lifetime program.

3. An expense-trend comparison program.

4. A repair-limits program.

5. A depreciation curve estimation program.

These programs are explained as follows (28:3-5):

The curve-fitting program (CURVEFIT) combines cost data on similar equipment to determine patterns in operating and maintenance expense. These patterns are updated periodically with the most current figures available.

The economic-lifetime program (LIFETIME) combines expense patterns with effective cost due to loss in resale value (depreciation), to determine the point in the equipment life cycle where rising operation costs overshadow the loss in value. This length of life is recommended as a replacement policy, since it gives a minimum average cost per period (MACP), usually expressed as minimum average annual cost. A shorter life cycle costs more on the average due to rising maintenance cost.

The trends comparison program (TRENDS) identifies upcoming replacements and those vehicles which are costing appreciably more or less than the average.

The repair limits program (REPAIRLM) produces tables of economic repair limits giving rules of thumb for repair vs. replace decisions. A very real dilemma arises when an older vehicle comes up for an unexpected repair. Does its limited remaining life justify the cost of the repair, or is the city better off getting rid of the unrepaired vehicle and buying a new one? If an upcoming repair will cost more than the corresponding limit value, a city is better off selling the vehicle in its unrepaired condition.

The depreciation curve program (DPRCURVE) shows the patterns of declining resale values indicated by actual experience. These patterns again by vehicle type, are used to establish the net cost due to lost value for each possible replacement cycle in the LIFETIME Program.

The information flow process in the PTI Vehicle Replacement Package is depicted in Figure 3-1.

PTI advises that since their program is relatively new and is still being tested by some activities, no single activity is making full use of the program. Several municipalities such as Seattle, Washington; Ventura, California; and Delray Beach, Florida, are working with the program and
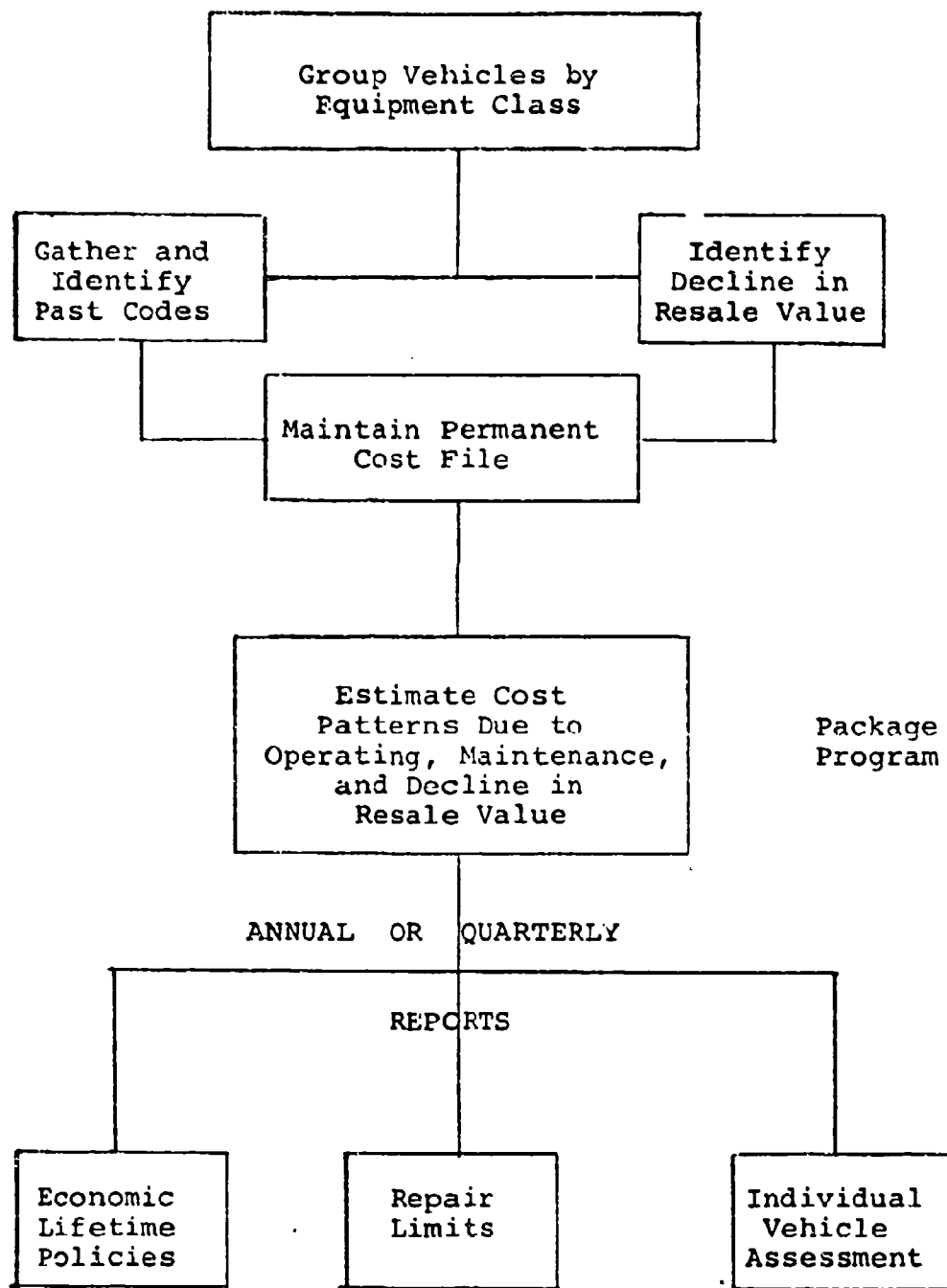
Figure 3-1

PTI Vehicle Replacement Package Flow Process
SOURCE (28:4)

have successfully loaded certain portions of it for use
(30). Other municipalities, however, have started imple-
menting the programs but have been disappointed with the
immediate results due to the lack of vehicle historical data.
A PTI representative advises that before an activity
attempts to utilize this package, they must insure that they
have the necessary historical data on hand if they expect to
realize any immediate benefits.

Bell Laboratories has designed a computer model to aid
vehicle managers in the determination of whether to keep or
replace vehicles (6:1). This model is based on the more
applicable costs involved in acquiring, maintaining, owning,
running, and retiring a motor vehicle. In addition to
assisting in the decision to keep or replace a vehicle, the
model also has the capability to forecast the future costs
that will be experienced if the vehicle is retained as well
as the costs that would be incurred by a replacement vehicle.
These capabilities give the Bell Laboratories' program,
called Computerized Automobile Replacement Scheduling (CARS),
"added dimension as an aid in determining future capital and
expense resource requirements [6:1]."

The economic model developed by Bell Laboratories was
designed with the idea that it should contain all of the
costs that would be considered as applicable in the economic
life of the vehicle when determining if and when a vehicle
should be replaced. This would then allow the "manager to
evaluate alternative decisions concerning the rate at which

vehicles are to be replaced on a vehicle group and on an individual vehicle basis [6:2]." The model also assumes that a retired vehicle will be replaced with a new vehicle which will be used for the same purpose.

Costs that are included in the Bell Laboratories' model include the amortized cost of a new vehicle, income tax, repair costs, and running costs (6:4-6). If adequate historical data have been kept on record, the application of these costs to the model does not present any problem. However, Bell Laboratories believes that only the amortization and income tax costs can be accurately projected into the future for the current or replacement vehicles. Bell Laboratories believes that "The pattern of future repair and running costs ...are not as clearly defined" and therefore are much more difficult to deal with (6:6). The CARS program, therefore, offers two "ways of estimating the pattern of repair and running costs for futu1 3 replacement vehicles [6:6]."

> The user may choose to allow the program to model the past histories of vehicles that are still in operation or have recently been retired and to use these estimates for all future replacement vehicles, or he may modify these models of past and current vehicle costs to reflect an expected change in the operating characteristics of new vehicles [6:6-7].

The CARS program is designed so as to allow various quantitative analyses related to the replacement decisions. These analyses include an analysis of the average economic life of a vehicle, expected remaining lives of particular vehicles, individual repair versus replace decisions, and various sensitivity analyses for inflation rate, change in

vehicle efficiency, and changes in the repair cost pattern (6:7-11).

Bell Laboratories provided the researchers with an analytical description of the economic model, but due to the fact that the model was still being developed and improved by Bell Laboratories, proprietary rights prevented further disclosure and discussion of the CARS program in this thesis. If further information is required by the reader, contact should be made with Operations Analysis Applications Group, Bell Laboratories, Halmdel, New Jersey 07733.

Dr. James Douglas, Associate Professor of Civil Engineering, Stanford University (9:1), states that "When costs are minimized to determine the economic life and time of replacement of public works equipment, those most often forgotten are for downtime and obsolescence." Even though by common sense alone it is obvious that these variables should be considered, they are often neglected. Dr. Douglas suggests (9:1) that perhaps the major reasons for their neglect "is that they are somewhat intangible, hard to define, and generally do not appear in the books of accounts."

In this study of the effect of downtime and obsolescence, Dr. Douglas found that the inclusion of these variables not only increased the cost of ownership, but also shortened the economic life of the equipment studies (9:12).

Automated/Fleet Management Activities

Of the seven automated/fleet management activities

contacted, five provided information that was helpful in the accomplishment of the research question. Review of the responses received revealed that the variables considered in the replacement determination were basically the same as those used by the Air Force, e.g., age, mileage, and maintenance costs. In addition, they considered another variable identifying resaleability.

A close review of the automated/fleet management activities also revealed that their primary customers are commercial activities that have fleets of automobiles for salesmen, representatives, and executives. Consequently, these activities assign a high priority to vehicle cosmotology and body style currency as well as maintenance and operating costs. With this emphasis on vehicle currency, the activities replace their vehicles at approximately two years of age and/or approximately 40,000 miles. Considering these two variables, age and mileage, some automated/fleet management activities also considered the time of the year that a vehicle should be replaced so as to obtain the highest resale value. To illustrate these points, Table 3-3 reflects the recommendations that Peterson, Howell and Heather, Inc. (PHH), Baltimore, Maryland, (27:3) provided in their 22 July 1964 newsletter to their clients concerning standard and intermediate size cars.

While these recommendations were published under conditions when an energy shortage was not a factor, the table does illustrate the importance that PHH places on timely

Table 3-3

VEHICLE REPLACEMENT RECOMMENDATIONS BY PETERSON, HOWELL, & HEATHER, INC. 1964		
Monthly Mileage Rate	Annual Mileage Rate	Replace
Over 3300	40,000 plus	After 12 months, on first birthday, but limited to October, November & December
2500 - 3300	30,000 - 40,000	18-month cycle -- April alternating with October, May with November
2000 - 2500	24,000 - 30,000	After 24 months, on second birthday
1500 - 2000	18,000 - 24,000	30-month cycle -- April alternating with October, May with November
1000 - 1500	12,000 - 18,000	After 36 months, on third birthday
Less than 1000	Less than 12,000	After 48 months, on fourth birthday

resale value, age, and mileage below 50,000. Subsequent to
the energy shortage, PHH has made some temporary changes to
the above policies so as to allow for unstable conditions
until such time that economic conditions once again stabilize
to a certain degree.

Summary

The results from the inquiries described in this chapter
did not provide the information expected by the researchers.
The replies did reveal several somewhat surprising findings,
however.

The researchers believe that it is quite significant
that a very small fraction of the municipalities, utility
companies, or commercial fleet operators, other than the
professional automated/fleet management activities, employed
any economic analysis methods to objectively determine when
their vehicles should be replaced. While a few activities
were in the process of generating historical vehicle infor-
mation management data, fewer yet were anywhere near the
implementation of an objective system. Most activities con-
tacted were using some type of substitute methods which
considered age, mileage, and the mechanics' subjective
analysis, with the most weight being applied to the latter.

The most valuable information was received from the
three research activities contacted. Each activity had an
aggressive operation and was very willing to share their
knowledge, experience, and mathematical findings with the

researchers. The analytical models provided a systematic and objective economic analysis of the replacement versus continued operation question.

With the emphasis that the automated/fleet management activities placed on cosmotology, body style currency, and resaleability, the researchers believed that the information provided by these activities was of very limited use to the evaluation of the Air Force vehicle replacement procedures. While the Air Force is concerned about the outside appearances of their vehicles, it places very little importance on whether or not the body styles are the latest. The Air Force is also concerned about the resaleability of the vehicles, but to date has not placed the emphasis in this area that is currently being applied by the automated/fleet management activities.

Although the research question did not provide the analytical equations and techniques expected by the researchers, it does show that many activities do use the same variables that have been used by the Air Force, i.e., age, miles, and maintenance costs. Since the expectations of the researchers were not fully realized, it was necessary to restructure the research hypothesis to address an evaluation of the variables used by the Air Force.

CHAPTER IV

RESEARCH HYPOTHESIS

General

This chapter will describe in detail the methodology and data sources used by the researchers in evaluating the research hypothesis. In addition, the base population for this thesis will be identified.

Population Description

The scope of this thesis has been limited so that the term commercial general purpose vehicle will describe a vehicle which is available from competitive commercial sources and is restricted to a weight of 12,000 pounds or less. The term commercial general purpose vehicle will exclude special purpose, fire fighting, materials handling, and base maintenance vehicles.

The universe selected for this thesis was limited to the light sedan, station wagon and pickup truck types of vehicle. These three types constituted 33% of the commercial general purpose vehicle category at the time this research was conducted.

The population selected for the purpose of this thesis consisted of all sedans, station wagons and pickup trucks maintained by the vehicle maintenance facilities on the

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bases of the Air Force Logistics Command (AFLC) and Air University (AU). The testing of the research hypothesis was accomplished using census data from the population for the period 1 October 1972 to 30 September 1973.

Research Hypothesis

The Air Force does employ the proper combinations of variables and factors to determine motor vehicle replacement requirements.

Background

As was shown in Chapter II, the analytical equations use used by commercial activities and other governmental agencies which were to have been obtained from the research question were to be evaluated using Air Force historical maintenance data. The results of this evaluation were to be compared to the results using current Air Force variables and factors in order to determine which indicators provided a minimum total annual operating cost per vehicle.

Because of the types of data received in response to the research question, specific analytical equations could not be identified for testing the research hypothesis. The results of the research question, however, did indicate that many of the commercial and governmental activities were using the same variables as the Air Force (age, accumulated mileage and repair costs). The researchers therefore decided to test the variables used by the Air Force using the historical maintenance data collected.

The three commercial general purpose vehicles selected by the researchers for analysis (sedan, station wagon and pickup truck) are accorded the same life expectancy: age is six years, mileage is 72,000, and the repair allowance is established by a chart contained in Air Force TO 36A-1-70. The scope of this effort was limited to analyzing the age and mileage variables, since the repair allowance tables are predicated on the age and accumulated mileage of the vehicle being evaluated. Should the results of the analysis of the research hypothesis show that either of the factors used with the variables are wrong, or the current variables and and/or miles are unnecessary for considering a vehicle for replacement, the repair tables will have to be analyzed through a separate research effort.

Source of Data

The Air Force Vehicle Integrated Management System (VIMS) was being implemented at all Air Force bases world-wide at the time this thesis was written. For this research effort, the data prepared and submitted by the Air Force Logistics Command (AFLC) and the Air University (AU) were used. These two commands were participating in the VIMS implementation by serving as test or pilot commands so that the output data from these two commands could be evaluated and revised as necessary before full implementation was initiated. Because of the time constraints for the completion of this thesis, only the data from these two commands were available for analysis. The specific data employed by

the researchers represented all sedans, station wagons and pickup trucks reported monthly by AFLC and AU for the period 1 October 1972 to 30 September 1973.

Nature of the Data Utilized

The data obtained from the Vehicle Integrated Management System (VIMS) provided an in-depth analysis of the vehicles selected for analysis. For each type of vehicle, the data were subdivided into the sixteen replacement codes in use where this research effort was conducted. For each replacement code, information such as average mileage driven for the period, costs of operation (per vehicle and per mile), and out-of-commission rates were obtained. See Appendix H for the specific data elements included in the VIMS report.

Data Collection Techniques

The Vehicle Integrated Management System (VIMS) is a management reporting system initiated at base level by the vehicle maintenance activity. When a vehicle is placed in the vehicle maintenance activity, an incoming inspection is performed on the vehicle by a vehicle operator. During this inspection, the inspector completes Department of Defense (DOD) Form 1351-2, "Vehicle Inspection Record," on which he records the various factors leading up to the determination of the replacement code to be assigned to the vehicle. Once the inspection is completed, the information entered on the DD Form 1351-2 is verified by the quality control inspector

and the completed form is sent to the transportation activity's Reports and Analysis (R&S) Section.

The R&A personnel extract the pertinent data from the DD Form 1351-2 and keypunch the data for loading on the base Burroughs 3500 (B-3500) computer. Once the data are loaded and verified by the R&A personnel, the B-3500 computer internally verifies inventory and vehicle registration number data with the base supply computer. Any data not verified by the base supply computer will be rejected by the B-3500 in the form of an error message.

Verified data are then stored in the base B-3500 until the 15th day of each month when the data are automatically transmitted to the Warner Robins Air Logistics Center's B-3500 computer for consolidation. These data are then transformed into the VIMS worldwide reports which are provided to the major commands, HQ AFLC and HQ USAF for management purposes.

Method Employed

In order to evaluate the validity of the variables age and mileage, the researchers employed multiple regression analysis. In such analysis, two types of numeric variables are used. Independent variables are those variables which, when assigned a value and taken either alone or with other independent variables, create an effect on the value of the dependent variable. Dependent variables are those variables which are hypothesized to be influenced by the independent variables. The values of the dependent variable will change

based on the number and type of independent variables used.

To measure the effect that different independent variables had on the selected dependent variables, the computerized "Stepwise Multiple Linear Regression Program" (SMLRP) was employed (12). The SMLRP model is a stepwise regression program in which the computer carries out the regression for each independent variable in turn. The results of the multiple regression can then be analyzed to determine which independent variables had a statistically significant effect on the dependent variable selected for evaluation.

The nature of the data did not permit the researchers to compute a cost oriented regression equation which would include both the age and accumulated mileage of the vehicles tested. As such, a full range of statistical tests could not be conducted to determine the significance of age and accumulated mileage to the cost per mile or cost per vehicle.

Two models were therefore constructed. The first model considered the age of the vehicles being tested, and the data used consisted of those vehicles which were categorized as over-aged (Replacement Code H), six years old (Replacement Code L) or five years old (Replacement Code P). The second model was developed around the accumulated mileage data available. The observations used were restricted to those vehicles categorized as exceeding 72,000 accumulated miles (Replacement Code J), between 60,000 and 72,000 accumulated miles (Replacement Code M), or between 48,000 and 60,000

and 72,000 accumulated miles (Replacement Code M), or between 48,000 and 60,000 accumulated miles (Replacement Code Q).

In both models, the rates per mile were considered to be the most appropriate dependent variables. Rates per vehicle per month were also considered as dependent variables, but were discarded when the miles per group of vehicles were analyzed. In the group of data concerning the age of the vehicles, it was discovered that vehicles over six years old were driven an average of only 65% as many miles per month as the five year old vehicles. A similar analysis of average miles driven per month for the vehicles grouped by accumulated mileage produced similar results (see Appendix G). As such, the analysis clearly indicated that the newer vehicles and the vehicles with less accumulated mileage were driven considerably more miles per month and therefore a meaningful comparison of cost per vehicle per month would not be appropriate. The researchers therefore decided to utilize rates per mile driven per month as the dependent variables for the analysis of the research hypothesis.

Results of Analysis

The analysis was divided into two categories: vehicles grouped by age and vehicles grouped by accumulated miles. For both categories, a confidence level of 0.95 was selected for the analysis by the researchers. This confidence level means that the researchers are confident that the null

hypotheses will be false 95% of the time that the researchers say it is false.

Age Category

For this analysis, the vehicles were grouped in three sub-groups of over-aged (Code H), six years old (Code L) and five years old (Code P). The first test in the analysis consisted of determining the effect that the age of the vehicles had on the cost per mile to operate that vehicle. The results of this test produced no statistical significance to indicate that the age of the vehicle had any bearing on predicting the cost per mile to operate a vehicle.

A second test attempted to determine the effect that age had on the number of direct labor hours required to maintain the vehicles for the period. Again, there was no significance detected between the age of the vehicle and the number of direct labor hours expended on the vehicle.

Further tests were conducted to determine if the age of the vehicle had any effect on either the Vehicle Out-of-Commission (VOC) rates or the Vehicle Down For Parts (VDP) rates of the vehicles being tested. The results of these tests indicated that there was no evidence to suggest that a vehicle over six years old experienced a significantly greater out-of-commission rate or down for parts rate.

From the results outlined above, the researchers drew the conclusion that the variable "age" could be considered as unnecessary in evaluating a vehicle for replacement. See

Appendix G-1 for the specific mathematical and statistical computations.

Mileage Category

For this analysis, the vehicles were grouped in three sub-groups of over 72,000 accumulated miles (Code J), between 60,000 and 72,000 accumulated miles (Code M), and between 48,000 and 60,000 miles (Code Q). The first test consisted of determining the effect that accumulated mileage had on the cost per mile to operate that vehicle. The results of the test indicated no statistical significance between the accumulated mileage and the cost per mile.

A second test analyzed the effect that accumulated mileage had on the number of direct labor hours required to maintain the vehicles for the period. The results of this test did show a statistical dependency between the number of direct labor hours required per vehicle and the fact that the vehicle had accumulated over 72,000 miles.

Although further tests indicated that there was no evidence in increasing VOC or VDP rates for vehicles accumulating over 72,000 miles, the researchers drew the conclusion that the variable "accumulated mileage" is in fact a necessary consideration for determining the eligibility of a vehicle for replacement because of the effect that the accumulated mileage had on the number of direct labor hours required. Although there was an increasing trend in direct labor hours for vehicles over 72,000 accumulated miles, the

researchers could not determine if the factor 72,000 was in fact optimum. Confirmation of a valid mileage limit will have to be accomplished through economic analysis and is beyond the scope of this thesis.

Summary

From the results of analyzing the research hypothesis, the researchers have concluded that the accumulated mileage on a vehicle does constitute a valid consideration in evaluating a vehicle for replacement. The mileage criterion, however, did not appear to present a strong case for replacement. Further analysis using worldwide data is necessary to determine if the accumulated mileage criterion should be retained or used until a better measure of replacement is determined.

The researchers have further concluded that the variable age does not appear to be a valid consideration in evaluating a vehicle for replacement. Further research in this area should be conducted once sufficient Air Force maintenance/ utilization data become available as the VIMS is fully implemented.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Purpose

The purpose of this chapter is to permit the researchers to state conclusions which have been derived as the result of evaluating the research question and the research hypothesis. Furthermore, any recommendations to be provided by the researchers will be stated herein.

Research Question

Early in the review of the responses received by the researchers as the result of the research question, it became evident that any formal programs in use by commercial activities were utilized only to compliment the judgment and experience of key management personnel. Furthermore, many of the criteria and evaluation procedures used by the key managers had not been documented. This fact could not help but disrupt the continuity of operations once the managers "in-the-know" had departed.

The researchers do not mean to suggest that programs or models, whether computerized or manual, should totally replace the evaluation or decision of a manager. A model or program is only a diagnostic tool and the resulting findings or recommendations must be subjected to the manager's

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interpretation and judgment. For continuity of operations in any activity, however, total programs and procedures must be fully documented and updated as necessary.

The greatest problem which faced managers in practically all activities contacted was the lack of historical maintenance/utilization data on which to base criteria or programs. This same problem was identified as one of the causes for the seemingly slow introduction of computerized vehicle maintenance/management systems. The efforts of the American Public Works Association to construct a centralized data bank for the gathering of historical data from various sources are particularly commendable.

After extensive evaluation of the programs and literature provided as the result of the research question, the researchers have concluded that the vehicle replacement methods employed by the Air Force are at least equal to those of some commercial activities and superior to most.

One additional area which the researchers identified concerned the duplication of research efforts by commercial and government activities. In many instances, for example, commercial activities were analyzing certain areas which the Air Force had already investigated and documented. Institution of lines of communication in the vehicle management industry, particularly between commercial and Department of Defense activities, would prove beneficial to both parties. The researchers recognize that there is a great deal of competition between commercial activities and that

proprietary rights cannot be violated. The exchange of ideas and data on a periodic basis between vehicle management functions, however, would possibly alleviate costly duplication of effort and enhance the overall goal of obtaining better ways to manage vehicular assets.

Research Hypothesis

The results of the research hypothesis were somewhat less conclusive and concrete than originally projected by the researchers. As such, a positive rejection or lack of rejection of the research hypothesis was not possible.

The results of this research effort did, however, point out possible considerations for further research. Of particular interest to the researchers was the fact that the age of the vehicle did not seem to be a necessary consideration in evaluating a vehicle for replacement.

Should further research confirm that the age of the vehicle need not be considered, several changes resulting in benefits could become evident:

1. Restructuring of the Replacement Codes. As was shown in Chapter I, the Air Force was using 16 replacement codes at the time this research effort was conducted, with plans to add additional codes (see Table 1-2). Elimination of the age criterion could reduce the sixteen codes to ten. For example, a seven year old sedan which has accumulated 62,000 miles would be coded as requiring replacement in one year for mileage rather than immediately for age. This would permit the Air Force to receive more service from

equipment which is not replaced solely because it is considered too old.

2. Restructuring of the Repair Allowance Tables. The repair allowance tables prescribed in TO 36A-1-70 at the time this thesis was accomplished are dependent on both age and mileage. If age is eliminated from consideration, the restructuring of the repair allowance tables would be required. The seven year old sedan with 62,000 miles which was used in the above example could be allocated more repair costs. With age as a consideration, the repair allowance would be 5%; however, with age not considered, the repair allowance would be 17%, thereby allowing more repairs to extend the service life of the vehicle (16).

3. Other considerations. Elimination of the age criterion and reducing the number of replacement codes would considerably reduce the possible confusion in deciding which replacement code to apply.

Although the researchers have concluded that accumulated mileage should remain a consideration for replacement, the conclusion is based on a lack of other definitive criteria. Further research could result in the identification of more meaningful replacement criteria at which time accumulated mileage could be discarded.

Recommendations

As the result of this thesis, the following recommendations are offered:

1. At the time this research effort was underway, the historical data bank of vehicle maintenance information being developed by American Public Works Association (APWA) under APWA Research Project 70-1 had not been completed. The researchers recommend that the Air Force evaluate the project once it is completed to determine if any benefits could be derived.

2. The researchers recommend that the Air Force initiate action to establish a periodic vehicle management symposium for commercial and federal agencies so that ideas and programs of mutual interest could be discussed and exchanged.

3. Further analysis is recommended to determine if the age of a vehicle is a valid variable for evaluating the vehicle for replacement. Once the Air Force Vehicle Integrated Management System (VIMS) is fully operational, data should be gathered so that vehicles of specific age through the entire life of the vehicle can be evaluated.

4. The researchers recommend that the accumulated mileage variable be subjected to further analysis once worldwide Air Force data become available to determine if it is necessary in evaluating a vehicle for replacement.

5. It is further recommended that any variables which are determined to be necessary in vehicle replacement evaluations be subjected to extensive economic analysis to determine a valid expectancy level for each variable.

APPENDIX A

STATES FROM WHICH
NON-GOVERNMENT ACTIVITIES WERE
SOLICITED FOR VEHICLE REPLACEMENT
POLICIES AND PROCEDURES

Northeast Region

    New York
    Pennsylvania

Northcentral Region

    Michigan
    Ohio
    Illinois

South Region

    Texas
    Florida
    Georgia

West Region

    California
    Washington
    Colorado
    New Mexico
    Arizona

SOURCE: Regions are as described in U. S. Department of Commerce, Bureau of the Census, "Geographic Identification Code Scheme," April, 1972, p. iii.

APPENDIX B

GOVERNMENT AND NON-GOVERNMENT
ACTIVITIES SOLICITED FOR INFORMATION

Government Agencies (7)

Department of Agriculture
Defense Nuclear Agency
Department of Commerce
United States Postal Service
General Services Administration
Ohio Department of Transportation
National Highway Traffic Safety Administration

Non-Government Agencies

Automobile Manufacturers (6)

General Motors Parts Division
General Motors Corporation
Ford Motor Company
American Motors Corporation
Chrysler Corporation
Chrysler Corporation--Parts Division

Rent-A-Car Companies (3)

Hertz
Avis
National

Airlines (4)

United Air Lines
Eastern Air Lines
Delta Air Lines
Trans World Air Lines

Municipalities (6)

City of Philadelphia
City of Chicago
City of Detroit
City of Seattle
City of San Francisco
City of Dayton

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Utility Companies (8)

> Ohio Bell
> Bell of Pennsylvania
> Pacific Telephone
> Mountain Bell
> Dayton Power & Light Company
> Detroit Edison
> Philadelphia Gas Works
> Houston Light & Power Company

Taxi Companies (5)

> Yellow Cab Company of San Diego
> Diamond Cab Assn, Miami, Florida
> Yellow-Checker Cab Co., Albuquerque, New Mexico
> Yellow Cab Company, Phoenix, Arizona
> Yellow Cab of Philadelphia

Research Activities (2)

> American Public Works Association
> Public Technology, Inc.

Automated/Fleet Management Activities (5)

> National Automobile Dealers Assn.
> Lever Brothers Co.
> Motor Vehicle Manufacturers Assn.
> National Association of Fleet Administrators
> Peterson, Howell, & Heather, Inc.

Telephone Contacts

Research Activities (1)

> Bell Laboratories

Automated/Fleet Management Activities (2)

> Control Data Corporation
> McCollugh Leasing

APPENDIX C

SAMPLE COPY OF THE GENERAL
TYPE LETTER SENT TO ACTIVITIES
REQUESTING DATA AND INFORMATION

Dear Sir

We are graduate students of the School of Systems and
Logistics, Air Force Institute of Technology, and are
conducting thesis research in the area of motor vehicle
management. The purpose of our research is to determine
an optimum method and combination of variables and factors
that may be used in determining fleet motor vehicle
replacement requirements.

We believe that this study will help reduce management
costs in operating the motor vehicle fleets as well as
provide guidance for future studies. Your assistance is
requested in this matter to help insure that the study
thoroughly covers the subject.

Would you please provide us copies of the policy, pro-
cedures and criteria used by your organization to deter-
mine motor vehicle replacement requirements. Because of
the limited scope of our efforts, we are primarily inter-
ested in the sedan and one-half ton pickup truck types of
vehicles. In addition, any quantitative data (i.e., miles
accumulated, annual maintenance costs, total maintenance
costs, etc.) and/or studies used by your activity to deter-
mine your motor vehicle replacement procedures and criteria
would be greatly appreciated.

For your convenience, please find enclosed self-addressed
pre-paid mailing labels. Should you desire an abstract
from our findings, please so advise when you provide the
information contained in our request.

Your contribution to this research study will be appreciated
and should measurably contribute to the requirements of Air
Force sponsored research.

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APPENDIX D

G.E.A.R.S.

Ground Support Equipment Replacement Analysis

Report #999

Purpose of Report:

- To provide accurate replacement forecasts for each motorized vehicle in Eastern's inventory.

- To provide a basis for accurate budgeting of capital funds for ground equipment replacement programs.

- To provide a sound basis for replacing ground equipment at the most economical period, thus reducing overall vehicle maintenance costs.

Input:

- See attached data source list.

Distribution:

- One copy of report to Ground Equipment Control.

Frequency:

- One copy of report every 6 months.

Field Explanation:

1. Date - Six digit field for date that computer generates the report (06/15/74)

2. Fleet Code - Three digit field indicating the fleet or vehicle type.

3. Vehicle I.D. Number - Maximum six alpha/numeric character field to indicate vehicle identification number.

4. Station Code - Three alpha character field indicating the station location of the vehicle (MIA, ATL).

5. Fleet Avg. 'T' - Maximum three alpha/numeric character field indicating the average of all period 'T' within the indicated fleet code for all E.A.L. Print IDA if insufficient data is available.

6. R^2 - Maximum five alpha/numeric character field indicating the index of determination of the regression line.

7. Period 'T' - Maximum three alpha/numeric character field indicating the number of the month (since the vehicle was purchased) that the AMC (average monthly cost) hits a minimum before it begins to increase. Print IDA, if insufficient data is available.

8. Variance to Avg. 'T'- Maximum four alpha/numeric character field indicating the variance or difference (plus + or minus -) between fleet Avg. 'T' and period 'T'. Print IDA if insufficient is available.

9. AMC - Maximum seven alpha/numeric character field indicating the dollar amount of the AMC (AVERAGE MONTHLY COST) during the indicated period 'T' Print IDA if insufficient data is available.

10. Calculated Repl. Date - maximum six alpha/numeric character field indicating the calculated replacement date of the vehicle. If insufficient data is available, print "IDA" followed by the number indicating the quantity of periods calculated without reaching 'T', i.e., if the computer is limited to running a projection equal to the number of periods of historical data, then a 36-month old vehicle could only be calculated through 72-months. If period 'T' is not reached in 72 months, then the computer would print IDA 72.

G.E.A.R.S. Replacement Formula:

$$C_{chain} = \left[B - \frac{S(T)}{(1+i)^T} + \sum_{t=1}^{T} \frac{E(t)}{(1+i)^t} \right] \frac{(1+i)^T}{(1+i)^T - 1}$$

Data Source for Formula:

NOTE: * Denotes Multiplication

B= Original Price (Source Document AA, Field 23)

S(T) = Salvage Value Function, Derived as follows:

      S = Terminal salvage value (source document AA, Field 23A)

      N = No. months equipment will be depreciated (source document AA, Field 23B)

      T = No. months for which the AMC (average monthly cost) is being calculated.

      For $S(T) > S \longrightarrow S(T) = B - (B/N * T)$

      For $S(T) \leq S \longrightarrow S(T) = S$

i = 0.00949 minimum return on investment per month

AMC = (C chain * i)

E = monthly maintenance expense, derived as follows:

    $\sum$ source document B, (Field 13 * field 14) + (Field 22 * \$10.00)

   + $\sum$ source document BB, (Field 12 * Field 13) + (Field 18 * \$10.00)

   = Total E for applicable month.

      NOTE: E is to be read into a linear regression program to obtain the regression
           coefficients (A & B1) and also the "Index of Determination", R^2, where E
           is the dependent variable and t (time in months) is the independent variable.

      E(t) = Expense function (average expense per month)

      $E(t) = A + \dfrac{(B1 * t) + (B1 * (t-1))}{2}$ where t is time in months.

In order to enter maintenance expense history which occurred previous to G.E.A.R.S.
implementation, source document E will be used to enter up to six years (72 months)
history into the computer files.

G.E.A.R.S.

Ground Support Equipment Replacement Analysis
Data Source for Report #999

REPORT FIELD	SOURCE	DOCUMENT	FIELD
1	-	Date Report Generated by Computer	
2	-	AA	5
3	-	AA	8
		or B	3
		or BB	8
4	-	AA	2
5	-	Avg. of all T's within applicable fleet code	
6	-	R^2 is derived from regression analysis.	
7	-	T is derived from replacement formula.	
8	-	The difference between fields (5) and (7)	
9	-	AMC is derived from replacement formula.	
10	-	Sum of purchase date and T indicated in month and year.	

EASTERN AIR LINES
G.S.E. DATA SYSTEM

GROUND SUPPORT EQUIPMENT REPLACEMENT ANALYSIS

REPORT 999   DATE ⁄ ⁄

FLEET CODE (13)	VEHICLE I.D. NO. (16)	STATION CODE (13)	FLEET AVG 'T' (13)	R^2 (15)	PERIOD 'T' (13)	VARIANCE TO AVG 'T' (14)	DATE AMC (7)	CALCULATED REPL. DATE (16)
220	2215	MIA	84	0.875	81	-3	61.75	03/74
220	2217	MIA	84	0.790	85	+1	59.65	07/74
220	2220	SJU	84	0.014	IDA	IDA	IDA	IDA60
221	2235	ATL	78	0.888	72	-6	83.70	12/75
221	2250	BOS	78	0.025	IDA	IDA	IDA	IDA72

② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ⑩   ①

APPENDIX E

CITY AND COUNTY OF SAN FRANCISCO

CENTRAL SHOPS
PURCHASING DEPARTMENT
800 QUINT STREET
SAN FRANCISCO, CALIF 94124

AUTOMOBILE LEASING STUDY
AND
REPLACEMENT RECOMMENDATIONS

NOVEMBER 1960

DATA AMENDED TO
JAN. 1974

UPON THE REQUEST OF THE FINANCE COMMITTEE OF THE BOARD OF SUPERVISORS, THROUGH MR. THOMAS J. MELLON, CHIEF ADMINISTRATIVE OFFICER, A STUDY WAS INITIATED BY THE PURCHASING DEPARTMENT, CENTRAL SHOPS, AS TO THE FEASIBILITY OF LEASING AUTOMOBILES FOR USE BY THE CITY AND COUNTY OF SAN FRANCISCO.

THIS STUDY WAS PRESENTED TO THE COMMITTEE AT ITS MEETING OF DECEMBER 15, 1965 WITH THE CONCLUSION THAT, EXCEPT FOR CLASS D AUTOMOBILES, LEASING PRESENTED LITTLE ADVANTAGE TO THE CITY.

IN CONJUCTION WITH THE REPORT SUBJECT, THE PURCHASING DEPARTMENT AND CONTROLLER'S OFFICE REPRESENTATIVES REVIEWED THE CITY'S FLEET MANAGEMENT AND FINANCING PROCEDURES AND MADE FURTHER RECOMMENDATIONS BASED ON THE PREMISE THAT THE OVER-ALL COST OF A VEHICLE INCLUDES:

     1. ORIGINAL PURCHASE PRICE
     2. OPERATIONAL COST
     3. MAINTENANCE COST (DOWN TIME)
     4. DISPOSAL VALUE (CREDIT)

AND WITH THE KNOWLEDGE THAT OVER THE PAST SEVERAL YEARS THE (1) ORIGINAL PURCHASE PRICE HAS INCREASED APPROXIMATELY 70%, WHEREIN WAGE INCREASES RELATED TO (3) MAINTENANCE COSTS HAVE RISEN 143%. IT CAN BE ANTICIPATED WAGE COSTS WILL CONTINUE TO INCREASE AT A FASTER RATE THAN THE COST OF VEHICLES.

IT WAS THEREFORE, CONCLUDED THAT IT WOULD BE TO THE BEST INTEREST OF THE CITY AND COUNTY TO ESTABLISH A REPLACEMENT CRITERIA MORE IN KEEPING WITH MODERN FLEET MANAGEMENT PRACTICE. THIS POLICY WOULD PROVIDE FOR AN EARLIER DISPOSAL DATE. IT WOULD ALSO RESULT IN LOWER MAINTENANCE COST AND HIGHT DISPOSAL VALUE PER UNIT OF EQUIPMENT. ADDITIONALLY, IT WOULD PROVIDE THE ADVANTAGE OF PERMITTING THE INITIATION OF A PREVENTATIVE MAINTENANCE AND INSPECTION PROGRAM ON THE PRESENT FLEET OF "GENERAL SERVICE" VEHICLES; AS RECOMMENDED BY THE FORBES STUDY WITHOUT THE NEED OF ADDITIONAL EMPLOYMENTS.

RECOMMENDED REPLACEMENT SCHEDULE:

GENERAL SERVICE VEHICLE:

COMPACT CARS - CLASS 8-9	4 YEARS OR 50,000 MILES
CLASS (STD. & INT'MED.) 5-6-7	5 YEARS OR 60,000 MILLS
CLASS 2-3-4	5 YEARS OR 60,000 MILES
CLASS 1	FULL MAINTENANCE LEASE - 3 YEAR MAXIMUM
LIGHT TRUCKS (½ - ¾ TON CLASS)	6 YEARS OR 60,000 MILES

Preceding page blank   72

AUTOMOBILE LEASING STUDY AND
REPLACEMENT RECOMMENDATIONS
PAGE TWO

POLICE VEHICLES:

STAR CARS (BLACK AND WHITE) CLASS 6 OR 7	2 YEARS, OR 70,000 MILES
UNDERCOVER CARS - CLASS 7	4 YEARS, OR 60,000 MILES
PATROL WAGONS	4 YEARS, OR 100,000 MILES
MOTORCYCLES SOLO	5 YEARS, OR 40,000 MILES
MOTORCYCLES 3 WHEELS	4 YEARS, OR 35,000 MILES
CLASS 1	4 YEARS MAXIMUM

FIRE DEPARTMENT VEHICLES (PASS. CARS):

CLASS 5-6	5 YEARS, OR 60,000 MILES**
B AND C CLASS 2-3	5 YEARS, OR 60,000 MILES*
LIGHT TRUCKS (½ TO ¾ TON CLASS)	6 YEARS, OR 60,000 MILES

     * INCLUDES LINE AND RELIEF SERVICE
    ** INCLUDES LINE, STAFF AND RELIEF SERVICE

SHERIFF'S VEHICLES:

STAFF CARS - CLASS 6-7	5 YEARS, OR 60,000 MILES
ROAD CARS (STATION WAGON) CLASS 6-7	4 YEARS, OR 75,000 MILES

    FACTORS THAT REQUIRE CONSIDERATION BE GIVEN TO ESTABLISHING A FIRM
REPLACEMENT POLICY FOR THE CITY FLEET:

    1)
        A) VEHICLES PURCHASED AT FLEET PRICE
        B) VEHICLES MAINTAINED AT PREVAILING UNION WAGES

    2)   COST OF STANDARD AUTOMOTIVE UNITS HAVE SHOWN NOMINAL
        INCREASES OVER PAST SEVERAL YEARS.

        EXAMPLE - 1960, 4 DOOR SEDAN @ $1975.00 (CLASS 6)
                 1974, 4 DOOR SEDAN @ 3300.00

                                      67% INCREASE

                1960, PICKUP @ $1741.00
                1974, "   3000.00   72% INCREASE

    3) CRAFT WAGES INCREASED 143% IN 14 YEARS

        1959-60 RATE - $123.40 PER WEEK
        1973-74 RATE - 300.60 PER WEEK

           INCREASE 177.20   143% INCREASE

    4) NUMBER OF UNITS MAINTAINED BY CENTRAL SHOPS HAS INCREASED AS
        FOLLOWS:

        A) PASSENGER AUTOS: JULY 1, 1961 - 509 UNITS
                        DEC.30, 1973 - 820 UNITS

                        INCREASE   311   61% INCREASE

        B) LIGHT TRUCKS: JULY 1, 1961 - 148 UNITS
                        DEC.30, 1973 - 350 UNITS

                        INCREASE   202 UNITS 136% INCREASE

AUTOMOBILE LEASING STUDY AND
REPLACEMENT RECOMMENDATIONS
PAGE THREE

  C) OVERALL FLEET INCREASE:

    JULY 1, 1959 - 1573 UNITS
    DEC. 30, 1973 - 2540 UNITS

     INCREASE 967   61% INCREASE

5) PRESENT BUDGETARY PROCEDURE REQUIRED EXCESSIVE TIME TO PROVIDE REQUIRED REPLACEMENT. THIS OFTEN RESULTS IN REPAIR COSTS OUT OF PROPORTION TO THE VEHICLE WORTH, PARTICULARLY WHEN AN OVERAGE VEHICLE SUFFERS EXTENSIVE DAMAGE OR REQUIRES MAJOR MECHANICAL REPAIRS.

6) FAILURE OF DEPARTMENTS TO PROJECT NEEDS AND BUDGET FOR REPLACEMENT VEHICLES IN TIME TO AVOID MAJOR REPAIR/MAINTENANCE.

THE DARTNELL SURVEY ON AUTOMOTIVE PRACTICES AND CONTROLS SHOWS THAT IN MEDIUM AND LARGE COMMERCIAL FLEETS AND VEHICLES ARE DRIVEN ON A AVERAGE OF 20,000 MILES PER YEAR AND ARE DISPOSED OF AT ABOUT 60,000 MILES OR BETWEEN 2ND AND 3RD YEAR IN SERVICE.

IT IS NOTED IN THIS SURVEY THAT PUBLIC UTILITIES ARE GENERALLY LOWER MILEAGE FLEETS AND TEND TO KEEP THEIR VEHICLES IN SERVICE ABOUT 5 YEARS.

HERE THE PREFERRED "PUBLIC IMAGE" IS ONE OF ECONOMY RATHER THAN PRESTIGE. THE REGENCY OF THE MODEL IS NOT A CONSIDERATION IN THE POLICY OF OPERATING THE CAREFULLY MAINTAINED CARS FOR FOUR TO SIX YEARS.

A RECENT STUDY OF LOCAL PUBLIC UTILITIES AND NEIGHBORING GOVERNMENTAL OPERATIONS INDICATE THAT 5 YEARS OR 60,000 MILES IS AN AVERAGE LIFE SERVICE FOR A LIGHT VEHICLE. THE CONSENSUS OF OPINION IS THAT MAINTENANCE COSTS INCREASE RAPIDLY BEYOND THAT POINT, WHILE VEHICLE EFFICIENCY AND DRIVER ACCEPTABILITY IS DECREASING.

DETAILED STUDIES AND RECOMMENDATIONS MADE BY THE AMERICAN PUBLIC WORKS ASSOC. AND THE STATE OF CALIFORNIA DEPARTMENT OF PUBLIC WORKS INDICATE SIMILAR FINDINGS.

THESE RECOMMENDATIONS ARE VERIFIED BY CENTRAL SHOPS EXPERIENCE IN OUR INVOLVEMENT WITH THE CITY FLEET. WE HAVE FOUND THAT THE VEHICLE REACHES ITS CRITICAL POINT AT 5 YEARS, OR 60,000 MILES.

AT THIS POINT OF SERVICE ALL WARRANTIES HAVE EXPIRED, THE VEHICLES DEPENDABILITY IS REDUCED, DOWN TIME INCREASES AND MAJOR REPAIRS ARE REQUIRED.

HIGHER MILEAGE FLEET OPERATIONS THAN THE ABOVE RECOMMENDATIONS ARE ECONOMICAL ONLY WHEN THE VEHICLES ARE HIGHWAY OPERATED. IN SUCH A CASE 100,000 OR MORE MILES CAN BE OBTAINED IN 2 TO 4 YEARS SERVICE.

THE FLEET OPERATED BY THE CITY OF SAN FRANCISCO IS ESSENTIALLY A LOW MILEAGE OPERATION DRIVEN UNDER EXTREME CONDITIONS. THE COMPARATIVELY SMALL AREA OF THE CITY, ITS VARIED TOPOGRAPHY AND CONGESTED TRAFFIC QUICKLY TAKES ITS TOLL OF OUR VEHICLES.

WE THEREFORE STRONGLY URGE THAT THIS RECOMMENDED REPLACEMENT SCHEDULE BE PUT INTO EFFECT AND BECOME THE POLICY OF THE CITY AND COUNTY OF SAN FRANCISCO.

     RESPECTFULLY SUBMITTED:

     A. M. FLAHERTY
     CITY SHOPS GEN'L. SUP'T.

APPENDIX F

REPRODUCTION OF CHAPTER IX
"MOTOR EQUIPMENT REPLACEMENT"
FROM AMERICAN PUBLIC WORKS ASSOC.
SPECIAL REPORT NO. 37, MOTOR VEHICLE
FLEET MANAGEMENT

IX. MOTOR EQUIPMENT REPLACEMENT

The question of replacement versus continued operation of an equipment unit has proven to be one of the most confusing and least understood of all the problems facing the equipment manager. The reason all too often is a lack of the recorded information needed for rational solution.

The correct solution requires a reasonably accurate knowledge of historical costs and a capability for estimating future costs. However, because of the general deficiency in historical costs, the problem seldom is approached as an economic analysis. Substitute methods – such as replacements based on time in service or accumulated mileage – frequently lead to erroneous decisions. The only replacement policy that will assure reasonably accurate decisions is a cost study of the individual

equipment compared to the group-cost experience of equipments having the same general capacity and service.

The elements of the economic replacement analysis can best be illustrated by a graph. Since the costs involved with the operation of an equipment unit primarily are functions of age (obsolescence) and accumulated miles or hours (usage), the rate at which these costs change with continued operation provides the elements needed to determine costs or savings resulting from replacements.

Chart 2 represents the various cost elements resulting from the 8-year operation of a truck, originally purchased for $8,000. It shows the various cost curves in terms of annual cost.
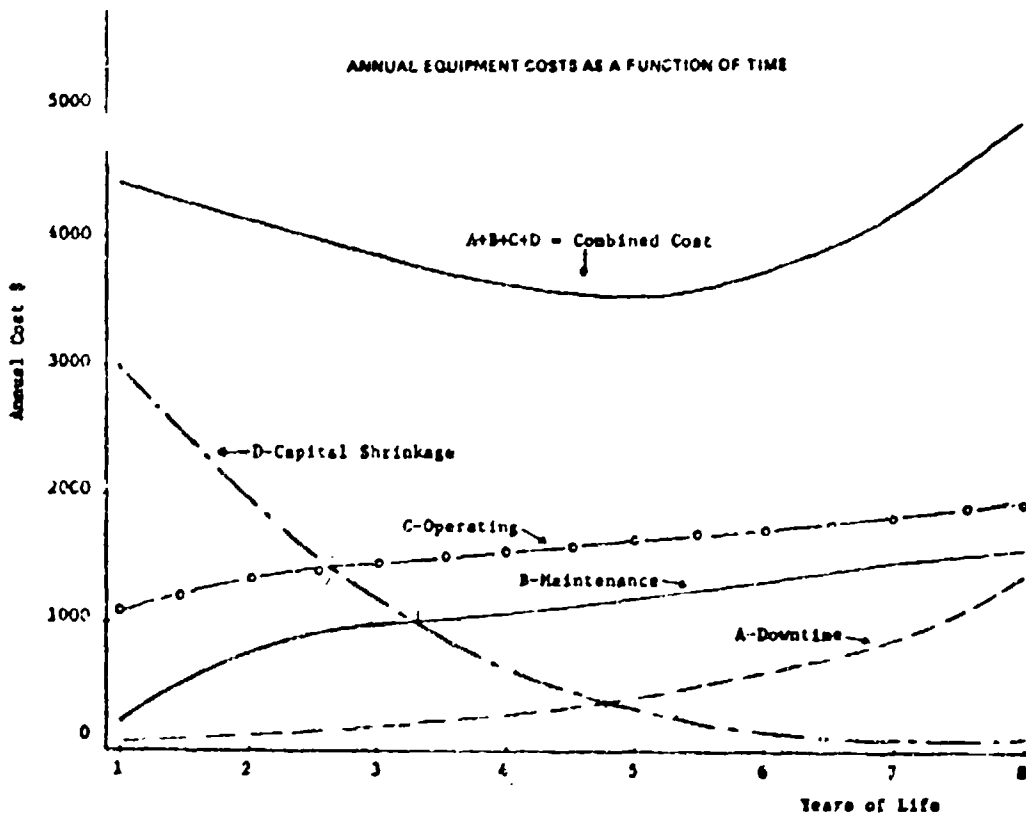
Curve A, cost of downtime, illustrates the

ANNUAL EQUIPMENT COSTS AS A FUNCTION OF TIME

A+B+C+D = Combined Cost

D-Capital Shrinkage

C-Operating

B-Maintenance

A-Downtime

Years of Life

Chart 2

Increasing cost of unavailability resulting from "out-of-service" for repairs. While it is relatively low during the first half-life of the truck, it shows a sharper increase in later years. Indeed downtime rate can be computed accurately by dividing the sum of the life capital shrinkage and maintenance cost by the number of days (or hours) in that life. In addition, indirect costs, which always should be considered, involve such elements as idle crew time resulting from equipment unavailability, substitute services employed, etc. Downtime cost is an essential element in any replacement study and must not be overlooked.

Curve B, cost of maintenance, indicates the increase in maintenance and repair costs (exclusive of accident) over the life span of the truck.

Curve C, cost of operation, represents the cost of fuel, lube, tires, batteries, and miscellaneous operating supplies.

Curve D, cost of capital shrinkage, represents the annual decrease in disposal or resale value of the truck. This curve differs from the accountant's evaluation of depreciation (usually a straight line) in that it relates to the "blue book" value of the truck at the end of each year and is considerably more accurate.

The combined curve represents the sum of curves A, B, C, and D, and thus is the total annual cost of owning a specific truck purchased at a price of $8,000.

To determine the point in the truck's life when replacement would be justified economically, an estimate must be made of the average annual total cost of a new truck over an 8 year period. Let it be assumed (as explained later) that a new truck can be purchased for $8,000 and will have a resale value of $200 eight years hence, that the total average cost of ownership, including capital shrinkage, amounts to $3,870 per year. On Chart 3, a horizontal line drawn at the $3,870 value intersects the combined cost curve of the old truck between the sixth and seventh year. This would be the theoretical time to replace the unit, provided unlimited funds were available for capital replacements.

Rarely does government experience such availability of funds. The various organizational units must compete for them, and the department with the best documented presentation, and financial justification receives the more favorable consideration.

Usually favored are those requests which develop the highest earnings in the form of savings. Therefore the fleet administrator must prepare his requests in a form that emphasizes the potential earnings (savings) that will accrue from the capital expenditures. Thus, in our overall perspective, attention should be given the savings that can result from improvements in services rendered.

A frequent ground rule of the budget director is that no requests will be considered whose earning rate

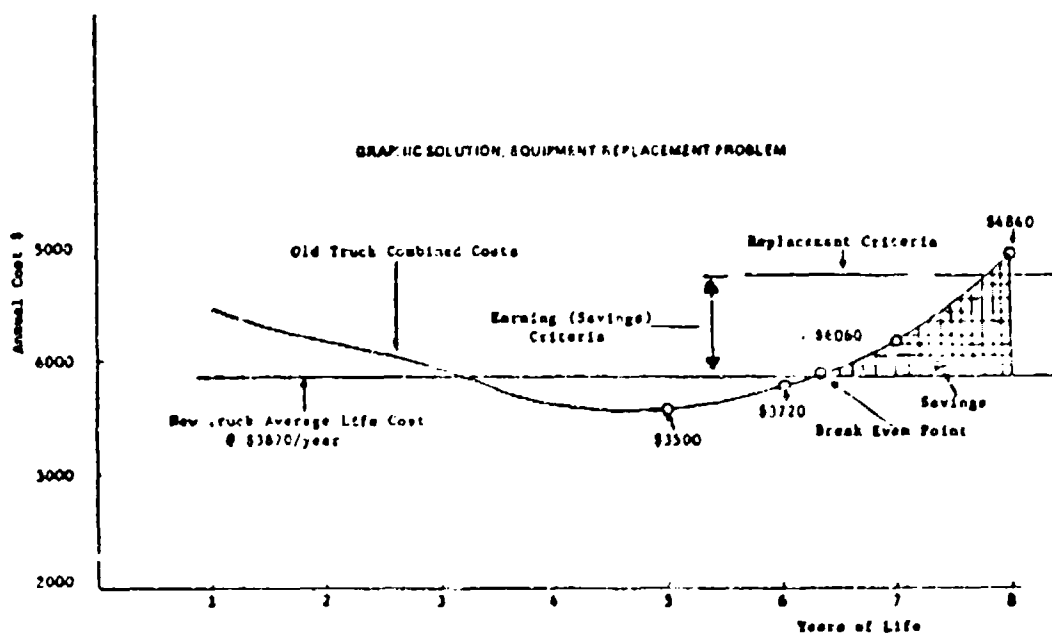GRAPHIC SOLUTION, EQUIPMENT REPLACEMENT PROBLEM

Chart 3

is less than a predetermined percentage of the capital expenditure requested. Such a policy has the effect of forcing all department heads to make economic analysis in defense of their requests. It also has the effect of determining priorities by rate of earning. It usually follows that earning estimates based on accurate recorded information are less controversial and therefore more convincing.

Referring again to Chart 3, the rate of saving if the truck were replaced at the end of the sixth year would be negative. If, on the other hand, replacement were at the end of the seventh year, the savings would amount to $190 per year ($4,060 less $3,870). This would represent an earning rate of 2.4 percent based on a net investment of $7,900 ($8,600 less $700). It is doubtful such an earning rate could compete in today's short supply of government funds. However, the rate of 12.3 percent earnings at the end of the eighth year should qualify the truck for replacement at that time.

Before proceeding to the practical solution of the problem, let's consider what the result would be if the truck had been replaced at the end of the sixth year. In this case there would be a loss (negative earning) of $150 per year, or 1.9 percent, based on a net capital investment of $7,900.

The graphs illustrated by Charts 2 and 3 aim to clarify the economic problem involved in equipment replacement. The figures were selected to emphasize the problem and do not necessarily reflect actual cost data. They do, however, approximate actual conditions which might be encountered in such a study.

Figure 36 illustrates a Replacement Analysis form designed for use in replacement studies. In this particular case it presents the analysis of the $8,000 truck referred to in describing charts 2 and 3.

Here is the step by step procedure:

1. Refer to the Equipment Replacement Data report (Fig. 32) for the last year and the first 6 months of the current year. There are 3 years involved in the replacement study: the last complete year, the current year, and the next or budget year. The listings will include all those equipment units approaching eligibility for replacement.

2. Confer with the supervisors responsible for the using agencies, equipment operations on the adequacy of equipments about to be replaced. Determine whether they should be replaced in kind or by a change of type and/or capacity. Every effort should be made to provide a replacement that meets the user's requirements and can be maintained at reasonable cost. The fleet administrator should keep abreast of equipment improvements as they appear on the market and relay appropriate information to the users.

3. Within each equipment group (APWA Code), analyze each unit, starting with the ones appearing to have the highest average annual cost. Analysis need only be carried out for a number of units comparable to the probable number of replacements that can be budgeted.

4. In the replacing-unit section:

a. Enter the description of the replacing (new) unit, using standard APWA nomenclature.

b. Enter the APWA Code number for the unit.

c. Determine the acquisition cost of the replacing unit and enter this amount in the blank space provided. Most dealers are willing to furnish reasonably accurate estimates covering the acquisition cost of new equipment. In this case it's $8,600.

d. Estimate the resale value of the replacing unit at the end of its standard life and enter this amount in the space provided. The Truck Blue Book will be a helpful guide in making this estimate. In this case $700.

e. Enter the net investment in the space provided. This is the acquisition cost less the resale value. In this case $7,900.

f. Refer to the Equipment Unit Cost Summary, Figure 25, Columns 5, 7, 9, 11, 13, and 15, indicating the total cost of the above APWA Code group which has been in service approximately 8 years. Determine the sum of the amounts indicated in these columns. divide this total by the item count indicated in Column 2, and enter the result in the space provided. In this case the amount was $21,000. This represents the total maintenance, operating, and downtime cost of similar units having 8 years of service.

g. Estimate the increase in the above cost resulting from anticipated price rises in wages, materials, and supplies and enter the percentage and dollar increases in the space provided. Experience over the last 15 years indicates an average annual increase of 2.5 percent in these cost areas. In the illustration the 8-year period would be subject to a total increase of approximately 20 percent for an average over the period of 10 percent or $2,100.

h. Enter the estimated total cost of maintenance, operation, and downtime in the space provided. In this case $21,000 plus

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┌──────────────────────────────────────────────────────────────────────┐
│                    EQUIPMENT REPLACEMENT ANALYSIS                      │
│                                        Equipment No. _____       │
│                                        Date: _____         │
│                                                                        │
│   REPLACING UNIT                                                       │
│                                                                        │
│   Description _____, Std. Life ___years, APWA Code _____. │
│   Acquisition Cost        $ _____   Total Maint. Oper. & Downtime $___│
│   Blue Book Value (Replaced) _____  Add ___% for Adjusted Cost   $___│
│   Net Investment                                                  $___ │
│                                                                        │
│                                  Total Cost ___years life     $___     │
│                      Average Annual Cost Per Unit $_____ per year    │
├──────────────────────────────────────────────────────────────────────┤
│   REPLACED UNIT                                                        │
│   Description _____, In Service Date_____ Years Service__  │
│                                                                        │
│                          Last Year 19__  Current Year 19__  Budget Year 19__│
│   1. Blue Book value last year  $____      $____            $____      │
│   2. Blue Book value this year   ____       ____             ____      │
│   3. Depreciation Cost          $____      $____           $____       │
│   4. Maintenance Cost            ____       ____            ____       │
│   5. Operating Cost              ____       ____            ____       │
│   6. Downtime Cost               ____       ____            ____       │
│   7. Total Cost                  ____       ____            ____       │
│   8. % Increase over previous year          ____%          ____%       │
├──────────────────────────────────────────────────────────────────────┤
│   ESTIMATED EARNINGS                                                   │
│   9. Net Investment      $____      $____            $____             │
│  10. Replaced Cost       $____      $____            $____             │
│  11. Average Replacing Cost ====     ====            ====              │
│  12. Earnings Per Year    (___)      ____            ____              │
│  13. Earning Rate        ____%      ____%           ____%              │
└──────────────────────────────────────────────────────────────────────┘
```

FIGURE 36

$2,100, or $23,100.

i. Enter the total cost of ownership per unit in the space provided. In this case $7,900 plus $23,100, or $31,000.

j. Enter the annual average cost of ownership per unit. In this case, $31,000 divided by 8 or $3,870 per year.

5. In the replaced unit section:

a. Enter the description of the unit to be replaced, its in-service date, and total years of service in the spaces provided. This information is listed on the Equipment Replacement Data listing (Fig. 32).

b. The replacement analysis usually is prepared shortly after the middle of the fiscal year in anticipation of the approaching budget year. There should be available a year-end report for the previous year of the Equipment Replacement Data (Fig. 32) and a 6-month listing for the current year. These will be used in determining entries to be made under the column headings "Last Year" and "Current Year," Lines 4, 5, and 6. The Blue Book values are entered on Lines 1 and 2 in all three columns; they are available from the Truck Blue Book published by National Market Reports, Inc., of Chicago.

c. Enter on Line 3 of all three columns the difference between the amounts shown on Lines 1 and 2.

d. Under the column heading "Last Year," entries on Lines 4, 5, and 6 may be read directly from the Equipment Replacement Data Listing (Fig. 32) for that year.

On Line 7 enter the total of Lines 3, 4, 5, and 6. On Line 9 enter the difference between the acquisition cost ($8,600) and the amount shown on Line 2. On Line 10 enter the total cost from Line 7; on Line 11, the average annual replacement cost computed in the Replacing Unit Section; on Line 12, the difference between Lines 10 and 11. On Line 13 enter the earning rate, which is determined by dividing the earning shown on Line 12 by the net investment shown on Line 9.

e. For entries on Lines 4, 5, 6, under the column heading "Current Year," refer to the Equipment Replacement Data Listings (Fig. 25) for the 6-month period of that year. Doubling the amounts shown on the listing for operating and downtime cost will be safe enough, since this will be slightly on the

conservative side. To estimate the annual cost of maintenance, it would be appropriate to review the equipment file containing the priced copies of all repair orders issued during the 6-month period – not only to determine if any major jobs were performed but to get a "feel" for the particular unit. Should any question arise, you might well call the unit into the shop and have the diagnostician prepare an estimate of the work needed to assure another 12 months of operation. Once the costs of maintenance, operation, and downtime are estimated, the same routine is followed as in the first column.

For the entries on Lines 4, 5, and 6 under the column heading "Budget Year," a careful estimate of these values is necessary. It is fairly certain that operating and downtime costs will increase, the former only slightly, the latter probably rather sharply. It is almost essential to prepare an estimate of the cost of repairs required to assure an additional 12 months of operation. This plus a review of the equipment file will help in arriving at a reasonably accurate estimate. A word of caution: Don't be tempted to pad this estimate. The record system, as designed, will soon highlight inaccuracies. It is more important to retain the respect of finance and budget review than to attempt a "fast one." Once the entries for Lines 4, 5, and 6 have been determined, the routine is the same for the first column.

As for the example illustrated by Figure 36, Line 8 shows the percentage increase over the previous year in terms of annual cost. It has been found that once the annual cost begins to increase, the percentage increase each year is approximately double that of the previous year. This rule of thumb will help you check the estimates in Columns 2 and 3.

An earning rate, as indicated on Line 13, is reasonably sure to receive favorable consideration when it ranges between 10 and 15 percent. Earning rates greater than 15 percent are considered good investments in almost any line of business.

The example illustrated represents the usual problem encountered when analyzing trucks and all types of off-highway equipment. Replacement studies involving sedans and station wagons frequently indicate profitable replacements after unusually short periods of ownership.

There is a much higher demand for used

passenger cars than for other types of motorized equipment. As a result the capital shrinkage rate may be substantially less.

Governments are in a particularly favorable position to take advantage of this situation since they usually are spared the taxes on new purchases that are imposed on private buyers. So it is not unusual for governments to experience a first-year depreciation rate as low as 10 percent.

The same type of replacement analysis applies to the passenger vehicle. As a result of the conditions discussed above, it is found that a favorable earning rate (because of the low net investment) will occur and justify replacement after as brief an ownership as

1 year. This is particularly true of passenger cars subject to high usage. For similar reasons, it frequently is found that the purchase of "top-of-the-line" passenger cars represent a lower ultimate cost to the government than stripped-down models of the same class.

Accordingly the fleet administrator should constantly be aware of the used passenger car market. Several publications provide this information.

In summary, it can be stated that savings which accrue from a replacement policy based on economic analysis will offset several times over the entire cost of the record systems discussed herein.

APPENDIX G

RESEARCH HYPOTHESIS
STATISTICAL RESULTS AND
MATHEMATICAL COMPUTATIONS

The purpose of this appendix is to provide the mathematical results and statistical computations used in evaluating the research hypothesis.

This appendix is divided into two parts: Appendix G-1 contains the calculations for the vehicles which were categorized by age; Appendix G-2 contains the calculations for the vehicles categorized by accumulated mileage.

Within each division, there are five parts:

- a) Average Miles per Vehicle Driven
- b) Cost per Mile Driven for Period
- c) Direct Labor Hours per Mile per Period
- d) Vehicle Out-of-Commission (VOC) Rates
- e) Vehicle Down for Parts (VDP) Rates

For the statistical analysis of the variables in this appendix, a confidence level of 0.95 was used. This confidence level means that the researchers are confident that the null hypothesis will be false 95% of the time that it is said to be false.

APPENDIX G-1

AGE CATEGORIES

a) Dependent Variable: Miles Driven per Period per Vehicle

Independent Variables: Over Six Years Old

Six Years Old

Five Years Old

Results

Independent Variable	Coefficient
Over Six Years Old	557.80
Six Years Old	755.65
Five Years Old	859.75

The results of the above analysis clearly indicate that, as a vehicle gets older, it is driven fewer miles per month. The following graph depicts the above results:
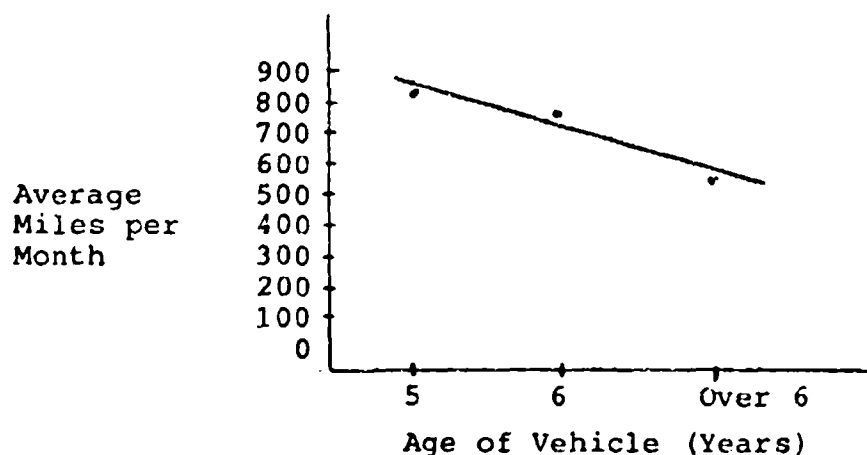
Age of Vehicle (Years)

b) Dependent Variable: Cost per Mile per Vehicle

Independent Variables: Direct Labor Hours per 1000

Miles

Over Six Years Old

Five Years Old

Results

Independent Variable	Coefficient	F to Remove	R^2
DL Hours per 1000 Mi	0.005902	9114.15	.9757
Over Six Years Old	-0.030832	0.14	.9815
Five Years Old	0.130626	2.59	.9819
Constant	0.065312		

Of the three independent variables analyzed, neither age variable was statistically significant at the 95% confidence level (F critical = 3.90). Furthermore, the age variables together accounted for only 0.62% of the explained variation.

c) Dependent Variable: Direct Labor Hours per 1000

   Independent Variables: Over Six Years Old

                           Six Years Old

Results

Independent Variable	Coefficient	F to Remove	R^2
Over Six Years Old	110.170427	0.98	.0085
Six Years Old	− 1.625038	0.00	.0085
Constant	7.139582		

Although there is a considerable rise in the coefficient for the vehicles over six years old, neither variable tested statistically significant to predicting the value of the dependent variable. In addition, neither age variable contributed significantly to the explained variation.

d) Dependent Variable: Vehicle Out-of-Commission (VOC) Rate

   Independent Variables: Over Six Years Old

   Six Years Old

Results

Independent Variable	Coefficient
Over Six Years Old	-0.668083
Six Years Old	2.851372
Constant	4.612083

Statistical tests were not performed on this regression; rather, the interaction between the coefficients was studied to determine if a vehicle over six years old experienced significantly higher out-of-commission rates. The researchers recognize that the VOC rates are dependent on the miles driven for the period; however, with the data available, there does not appear to be a significant increase in VOC rates as a vehicle exceeds the age of six years.

e) Dependent Variable: Vehicle Down for Parts (VDP) Rate

Independent Variables: Over Six Years Old

Six Years Old

Results

Independent Variable	Coefficient
Over Six Years Old	-0.897667
Six Years Old	0.920879
Constant	1.771667

Statistical analysis was not performed on this regression; rather, the interaction between the coefficients of the dependent variables was studied to determine if a vehicle over six years old experienced significantly greater out-of-commission rates because of parts nonavailability. While the researchers recognize that the VDP rates are dependent on the number of miles driven for the period, the results of the analysis indicate that there does not appear to be a significant rise in the VDP rates for vehicles over six years old.

APPENDIX G-2

MILEAGE CATEGORY

a) Dependent Variable: Miles per Vehicle per Period

Independent Variables: Over 72,000 Accumulated Miles

Over 60,000, less than 72,000

accumulated miles

Over 48,000, less than 60,000

accumulated miles

Results

Independent Variable	Coefficient
Over 72,000 accumulated miles	1155.58
Over 60,000 less than 72,000	1091.19
Over 48,000 less than 60,000	1453.48

As was evident in the vehicles categorized by age (see Appendix G-1), the vehicles with more miles accumulated are driven fewer miles per month. It is recognized that it is common practice to send newer, less used vehicles on trips off-base involving greater distances than on-base use. It is still impossible to draw a meaningful comparison between vehicles using rates per month when the mileage driven per vehicle varies so greatly.

The following graph depicts the above figures:
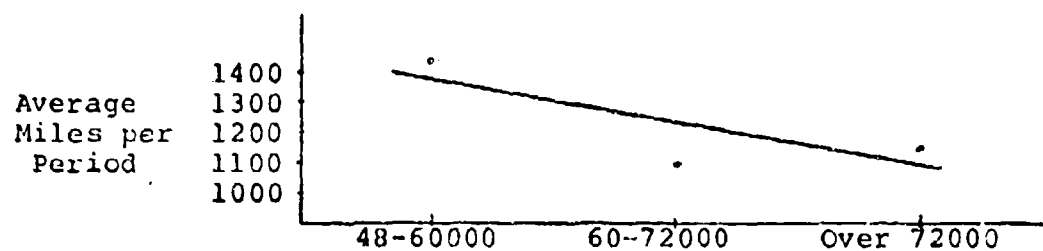
b) Dependent Variable: Cost per Mile per Vehicle

Independent Variables: Direct Labor Hours per 1000

Miles

Over 72,000 Miles Accumulated

Between 48-60,000 Accumulated

Miles

Results

Independent Variable	Coefficient	F to Remove	R^2
Dir Lab Hrs/1000 Miles	0.022947	197.86	0.5480
Over 72,000 Miles	0.001145	0.00	0.5512
48-60,000 Miles	0.018206	0.99	0.5512

Neither accumulated mileage variable proved to be statistically significant at the 95% confidence level (F critical = 3.90). Neither variable contributed to the explained variation in the regression equation.

c)   Dependent Variable: Direct Labor Hours per 1000 Miles

Independent Variables: Over 72,000 Accumulated Miles

Between 60,000-72,000 Miles

Results

Independent Variable	Coefficient	F to Remove	R^2
Over 72,000 Miles	2.045718	5.88	0.033
Between 60-72,000 Miles	0.621531	0.51	0.036
Constant	3.429288		

In this analysis, the fact that a vehicle had accumu-
lated over 72,000 miles was statistically significant at
the 95% confidence level (f critical = 3.90).   In addition,
the variable "over 72,000 miles" accounted for over 3% of
the explained variation.   Consideration is then given to the
fact that the vehicles which have accumulated over 72,000
miles are driven fewer miles per period than the vehicles
which have accumulated fewer miles.   If the higher mileage
vehicles had been driven as many miles per period as the
lower mileage vehicles, the statistical significance would
have been even greater.

d) Dependent Variable: Vehicle Out-of-Commission (VOC) Rate

   Independent Variables: Over 72,000 Accumulated Miles

   Between 60,000-72,000 Miles

Results

Independent Variable	Coefficient
Over 72,000 Miles	-0.178959
Between 60,000-72,000 Miles	-0.870210
Constant	10.319892

Statistical analysis was not performed on this regression; rather, the interaction of the variable coefficients was studied to determine if a vehicle which had accumulated over 72,000 miles experienced more out-of-commission time compared to a vehicle which had accumulated less mileage. The researchers recognize that the out-of-commission rates are dependent on the number of miles driven for the reporting period. The results of the analysis, however, indicate that there does not appear to be a significant rise in VOC rates for a vehicle which has accumulated over 72,000 miles.

e) Dependent Variable: Vehicle Down for Parts (VDP) Rate

Independent Variables: Over 72,000 miles

Between 60,000-72,000 miles

Results

Independent Variable	Coefficient
Over 72,000 miles	-2.717436
Between 60-72,000 miles	-1.586736
Constant	5.344769

In this regression, the interaction of the variable coefficients was studied to determine if vehicles accumulating over 72,000 miles experience more downtime due to parts nonavailability. Here, too, VDP rates are dependent on miles driven per period; however, the analysis indicates that there is no apparent rise in VDP rates for a vehicle which has accumulated over 72,000 miles.

APPENDIX H

VEHICLE INTEGRATED MANAGEMENT SYSTEM

DATA ELEMENTS

(Sample Data)

Replacement Code	Qty	Tot Direct Labor Hrs	Direct Labor Hrs/1000 Mi	Direct Labor Hrs/Vehicle	Mile /Veh	Cost /Mi	Cost /Veh			
A	175	635	3.9	3.6	958	0.05	47.56	1.37	3.54	3.22
B	79	227	4.3	2.9	672	0.06	37.19	0.16	1.74	1.93
C	44	163	2.9	3.7	1,285	0.04	49.82	0.17	2.84	2.19
D	3	6	2.5	2.5	900	0.05	41.19	0.09	1.57	1.57
G	35	116	3.9	3.3	858	0.05	47.16	1.22	6.01	7.24
H	75	238	4.3	3.2	741	0.05	39.16	1.55	3.33	4.95
J	41	246	5.3	6.0	1,122	0.07	73.75	0.65	6.65	6.65
K	36	182	4.2	5.1	1,200	0.05	61.80	0.54	7.20	8.16
L	51	129	1.9	2.5	1,117	0.03	43.51	3.55	3.72	6.27
M	22	121	4.5	5.5	1,225	0.07	66.91	3.45	5.21	6.66
N	29	185	9.2	6.4	695	0.10	67.21	1.21	6.81	8.12
P	19	111	6.	5.9	956	0.08	77.62	5.52	6.95	12.48
Q	10	48	3.5	4.8	1,385	0.05	63.90	4.77	3.53	3.31
R	10	33	4.0	3.3	840	0.06	53.09	1.78	5.08	7.12
T	154	444	2.3	2.9	1,264	0.04	49.25	0.50	2.22	2.72

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MAJOR JOHN A. REIDY, JR.

Major Reidy is a Regular Officer in the United States
Air Force. He has served in management positions in both
the airmunitions and logistics career fields. His assign-
ments include detachment, numbered Air Force and major air
command levels.

Major Reidy entered AFIT from HQ AFLC where his
assignment entailed the management of the Air Force Vehicle
Program. His responsibilities included the requirements
determination, funds control, distribution, supply control
and disposition of all motor vehicles operated worldwide by
the Air Force.

Major Reidy holds a Bachelor of Science in Nuclear
Engineering from the University of Notre Dame.

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BIOGRAPHICAL SKETCH

MAJOR DONALD A. SCHNEIDER

Major Schneider is a career officer in the United States Air Force. He has served as a manager in both the working level and staff level of logistics.

Approximately 50% of his Air Force career has been spent in the supply field with the other 50% spent as a logistics officer. His assignments include detachment, squadron, wing, air division, numbered Air Force and major air command levels. From 1971 to 1973 he was assigned to HQ TAC to manage the Command War Reserve Materiel program.

Major Schneider holds a Bachelor of Science in Agricultural Education from Kansas State University.